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REVISED STRUCTURAL TECHNOLOGY EVALUATION PROGRAM (STEP) USER'S MANUAL FOR STRUCTURAL SYNTHESIS

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NOVEMBER 1981

FINAL REPORT FOR PERIOD JANUARY 1979 TO NOVEMBER 1981

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This technical report has been reviewed and is approved for publication.

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This report presents the description of a structural synthesis program used within the Structural Technology Evaluation Program (STEP). This program is the revised version of APAS III. The reversion includes implementation of a fatigue crack-growth analysis methodology which realistically accounts for the spectrum load interaction effects to crack growth. Additional work was to add to the program the capability of producing fighter aircraft load spectra.

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SUMMARY

This report presents the results of a research and development effort performed under Air Force Contract F33615-77-C-3121, entitled: "Improved Methods for Predicting Spectrum Loading Effects." The objective of this program was to update the crack-growth prediction technology required for implementation of the damage-tolerance control procedures throughout the life cycle of any weapon system. Primary efforts devoted to development of a preliminary design level damage-tolerance analysis method were first to formulate a crack-growth life-prediction method suitable for use in the preliminary design stage of configuration development. A crack-growth prediction module, PREGRO, which utilizes a spectrum characterization method, was then incorporated into the Automated Pre-design of Aircraft Structure (APAS III), a multistation structural synthesis procedure of the Structure Technology Evaluation Program (STEP). The figure on page vi is representative of the overall STEP system. The General Interactive Executive Management System (GEMS) is the executive. Part of GEMS is an application executive (APEX). The Application Data Manager (ADM) provides the data base management and pre/post processing of data for application programs. APPL shown in the figure represents an application program (batch) with an APPLIN input file and APPLOUT output file. APPLGR represents an interactive graphics application program. The figure on page vii shows the relationship of the various application program modules to the data files preprocessed by the Application Data Manager (ADM) and output data files post-processed by the ADM for inclusion in the data base.

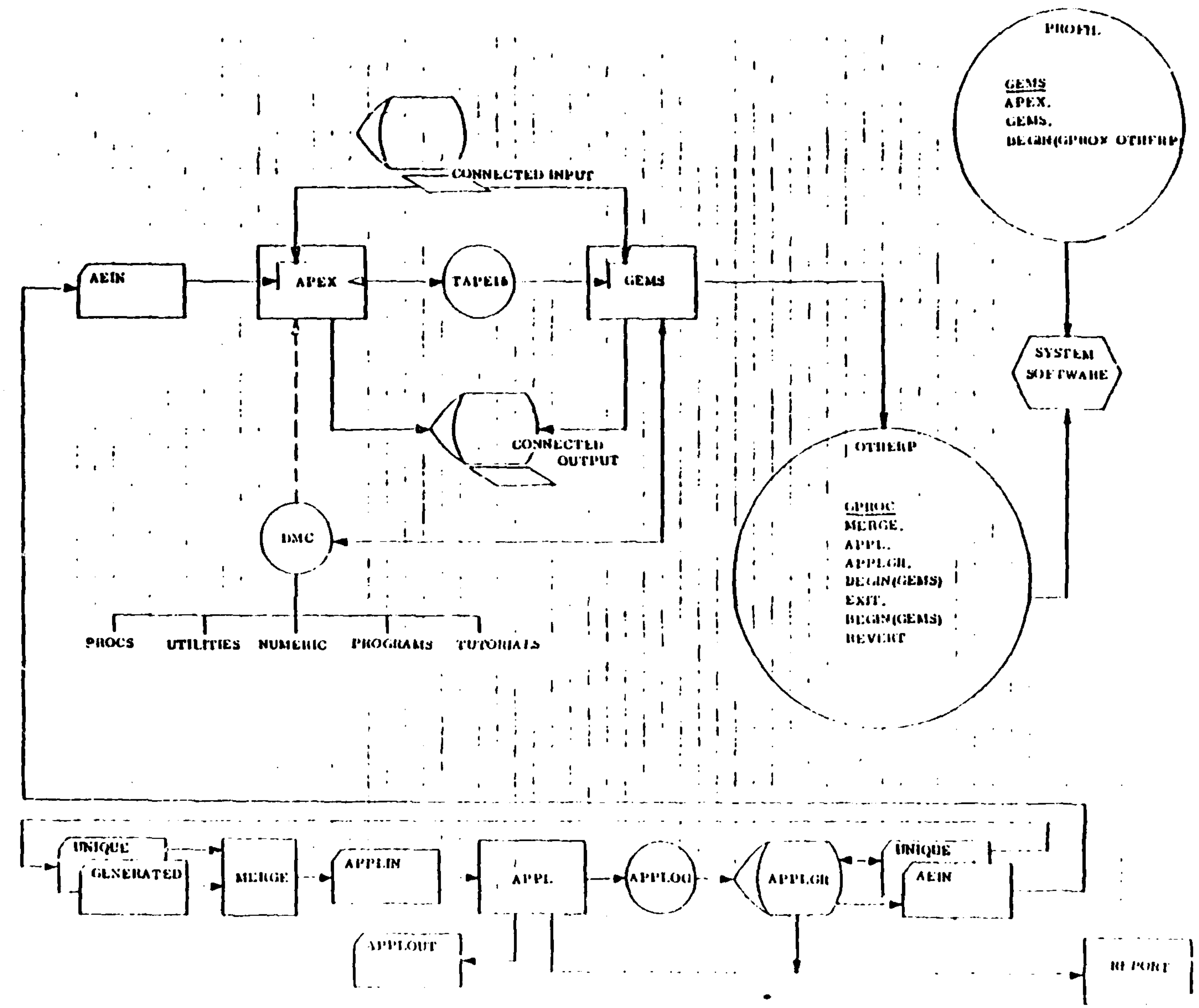
PREGRO performs a cycle-by-cycle crack-growth analysis of a uniblock flight spectrum which accounts for the load interaction effects to obtain the crack-growth rate per flight $(da/dF)_j$ and a measure of the stress intensity factor $\bar{K}_j$ for j values of initial crack sizes. It then characterizes an equivalent growth-per-flight equation (i.e., $da/dF = c\bar{k}^{\lambda}$) to obtain the growth rate parameters c, λ, and $(\overline{\Delta\sigma^2})^{1/2}$ through a least-square-fit routine. The final crack-growth life is calculated through the linear approximation technique.

Supplementary effort was directed toward extending the utility of APAS for conducting rational preliminary design trade studies on different aircraft categories. These tasks consist of restoration of the full range of stress intensity factor correction function for riveted stiffened panels containing large cracks, an extension of the crack-growth analysis process to include unstiffened plate construction concepts, an extension of the load spectrum library to include a typical spectrum for a lightweight fighter aircraft, and incorporation of an alternate means for specifying load spectrum.

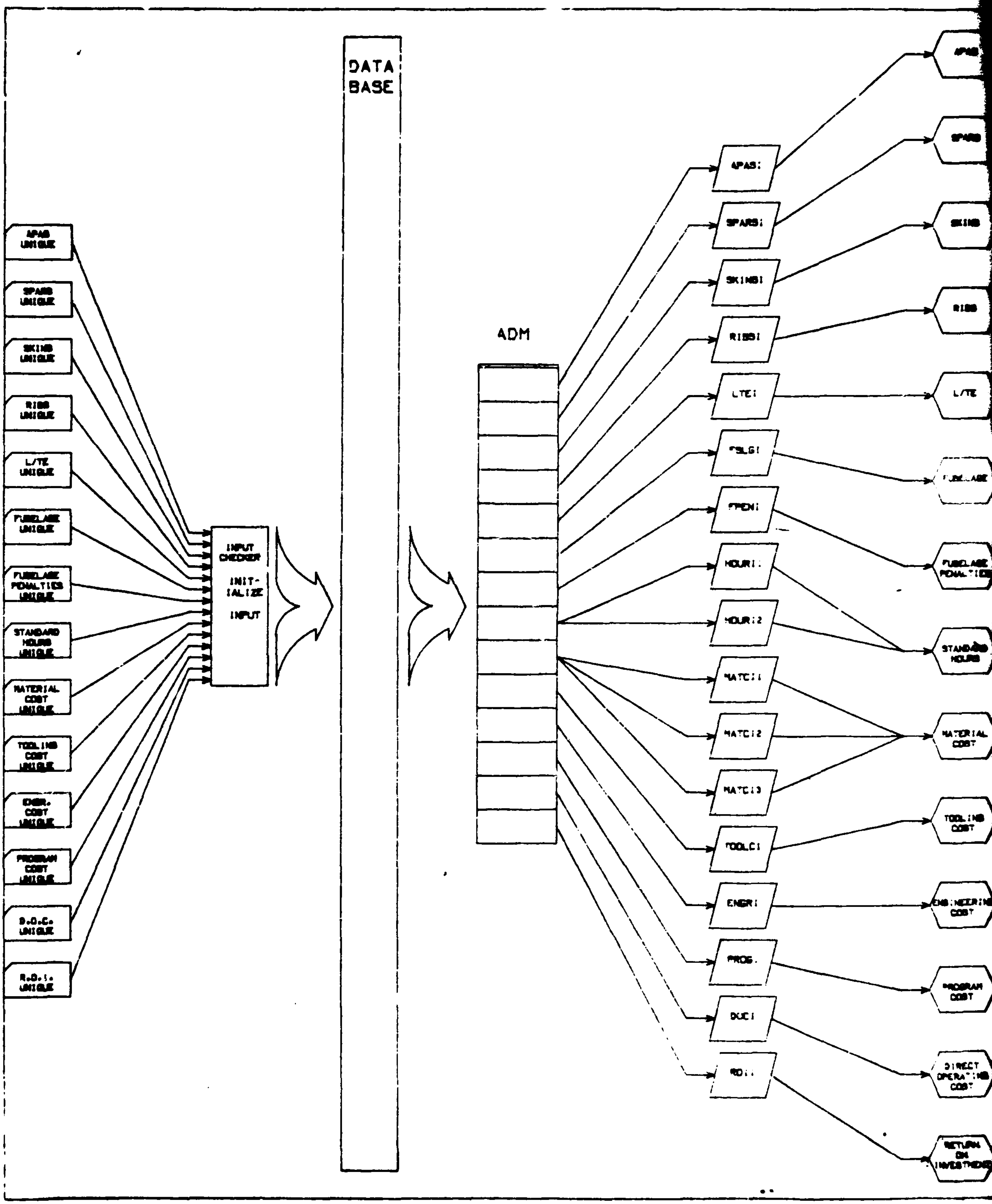
FOREWORD

This report was prepared by the Rockwell International Corporation, North American Aircraft Operation, Los Angeles, California, under Air Force Contract F33615-77-C-3121, Project 2401 "Structural Mechanics," Task 240101, "Structural Integrity for Military Aerospace Vehicles," Work Unit 24010120," Improved Methods for Predicting Spectrum Loading Effects." This work was administered under the direction of the Air Force Wright Aeronautical Laboratory, Flight Dynamics Laboratory, Structure and Dynamics Division, Wright-Patterson Air Force Base, Ohio. Mr. Robert M. Engle was the project engineer.

This work was accomplished by personnel from the Fatigue and Fracture Mechanics Group, Dynamics Technology, Structural Systems, supervised by George E. Fitch, Jr., supervisor, Joseph S. Rosenthal, manager, and Dr. Leslie M. Lackman, director. James B. Chang was the program manager and principal investigator. The major task performed was to implement a crack-growth analysis procedure which accounts for the load interaction effect of the flight spectrum to crack growth into the APAS III, a structural synthesis procedure.



STEP - Overall System Flow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R.O.I. UNIQUE
INPUT CHECKER
INIT-IALIZE
INPUT
DATA BASE
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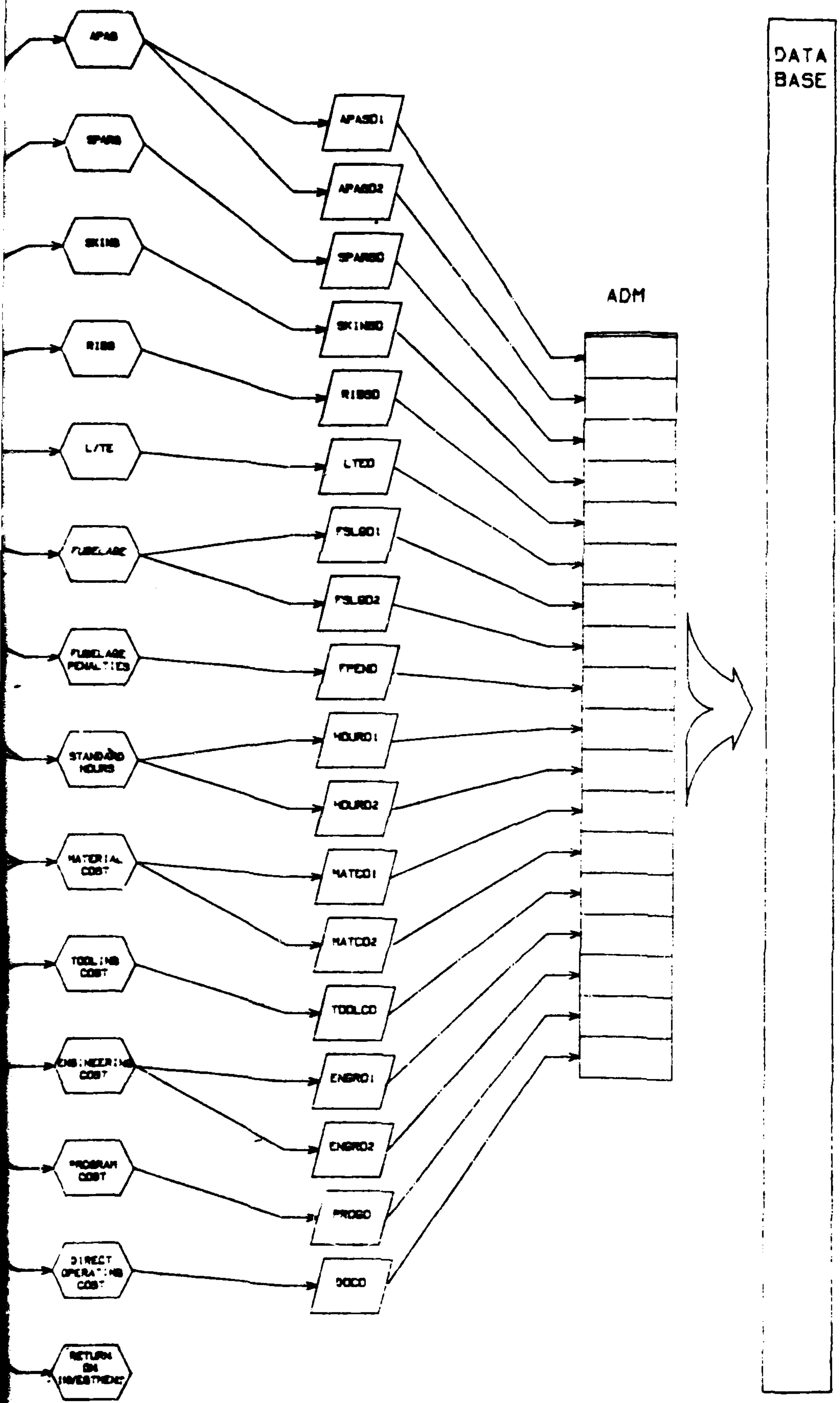

Data Flow Through the STEP Program Modules

1 2

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SECTION I

INTRODUCTION

Automated Pre-Design of Aircraft Structure (APAS) is a multistation structural synthesis procedure designed to perform structural sizing and detail design box beam structure. Development of this program was started at General Dynamics Convair Division in 1972. The original version of APAS was limited to static-strength considerations. The procedure was further developed to provide the addition of fatigue and fracture mechanics design criteria and multimaterial capability including advanced composite materials. This version of APAS was identified as APAS III, which represents a unique capability for evaluating the weight impact of various design criteria that may be considered for the primary structure (fuselage shells and wing boxes) of transport aircraft. Criteria that may be evaluated by APAS III include material selection, static loads, geometry, structural configuration, minimum gage limits, fatigue life, crack-growth life, and residual strength. Reference 1 described the APAS III program in detail.

The crack-growth module in APAS III lacks the capability of accounting for load interaction effects such as tensile overload retardation and compressive load acceleration. Therefore, to utilize APAS III in the preliminary design trade-off studies, a false indication on the calculated weight panelty might occur when a candidate structural component is sized based on the crack-growth analysis result. Under Air Force Contract F33615-77-C-3121, "Improved Methods for Predicting Spectrum Loading Effects," a research effort has been devoted to develop a crack-growth module, PREGRO, which realistically accounts for the load interaction effects. This crack-growth module was then incorporated into a modified APAS III. The modified version of APAS III is identified as APAS IV in this report.

Supplementary effort was also directed toward several tasks which are aimed at extending the utility of APAS for conducting rational preliminary design trade studies on different aircraft categories. These tasks consisted of the restoration of the full range of stress intensity factor correction functions developed by Poe for riveted stiffened panels containing cracks into APAS IV, extension of the APAS IV crack-growth analysis process to include unstiffened plate construction concepts, extension of the load spectrum library of APAS IV to include a typical spectrum for a light-weight air-to-air fighter, and incorporation of an alternate means for specifying load spectra. Reference 2 documents the development efforts of the abovementioned tasks. This report provides the guidance to the user for executing APAS IV.

SECTION II

COMPUTER PROGRAM CAPABILITIES

2.1 GENERAL DESCRIPTION

The technical approach used in APAS IV is applicable to any closed section beam-like structure, and it is typical of the procedure used in the early design phase of aircraft structure. The overall approach makes use of a point design/analysis/redesign process that is iterated until an acceptable design is produced. Figure 2-1 presents the functional flow chart for the approach used in the APAS IV computer program. This flow chart outlines the major analysis and design loops of the program. A detailed discussion of the theoretical basis for the analysis is presented in Section 4.1.3, LIMITATIONS AND RESTRICTIONS.

2.2 FUNCTIONS PERFORMED

The APAS routines perform structural sizing and detail design of box-beam structure. Inputs to the program include component geometry, structural elements, flight profile/load spectrum, and external loads. The structural analysis may select from the following: criteria, materials, geometry, static strength, stability, fatigue, fracture, and residual strength.

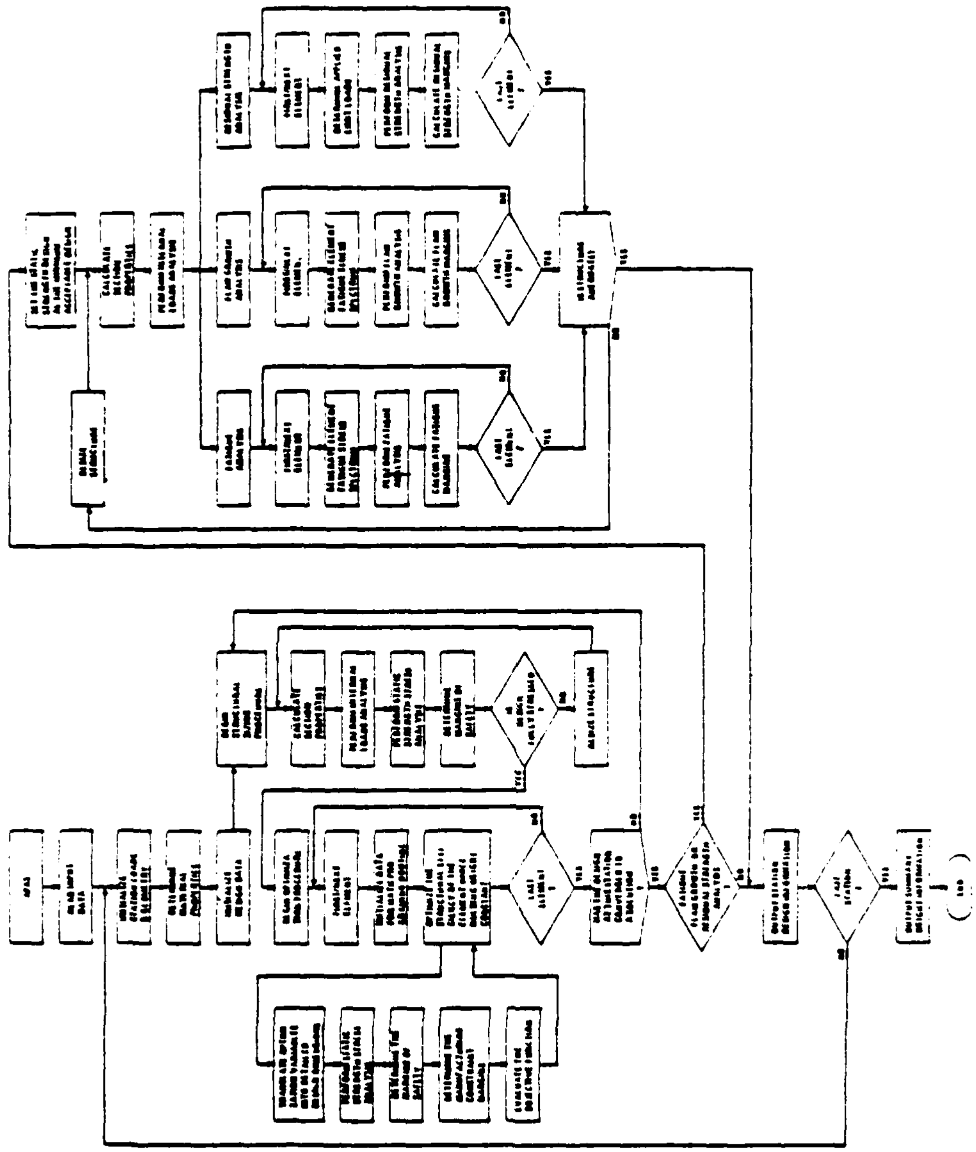

Figure 2-1. APAS Functional Flow

SECTION III

FUNCTION DESCRIPTION

3.1 TITLE OF FUNCTION

This section discusses APAS, the automated predesign of aircraft structure program.

3.2 DESCRIPTION OF FUNCTION

The APAS IV program is highly modular to facilitate modifications and additions. This modular approach has resulted in a large number of subroutines which are briefly described below. A complete layout of functional relationships of these subroutines is presented in Figure 3-1.

A skeletal framework was initially laid out for APAS IV with dummy subroutines to provide for future expansion of the program. Some of the dummy subroutines still exist, and the functions meant to be performed by these routines are also described below. The dummy routines mainly concern themselves with additional input and output options and do not affect the basic problem solving functions of the program.

APAS

This is the overall driver program that calls the input, output and processing routines.

BOXLDS

This subroutine performs a box beam internal load solution at a cross section and computes the complex bending stresses and shear flows for unit load components.

BUCKLE

This subroutine performs a panel buckling analysis for general instability of simply supported curved orthotropic panels in bi-axial loading with shear.

CHKBT

This subroutine checks the input BEE and TEE variables for illegal values.

CLAMDA

This subroutine performs a least square fit procedure to calculate the power exponent, ψ and the growth rate constant, c, for an equivalent crack growth per flight rate equation.

CONVRG

This subroutine determines when to stop the redesign iteration process based on the input convergence criteria parameters.

CORREC

This subroutine calculates the stress intensity factor width correction factor and combines it with the other stress intensity correction factors.

CPLIM

This subroutine is a recovery procedure which will be executed in the event of a CP time limit. It causes the values of output variables at the time of CP time limit to be output. This subroutine will be nonfunctional if the subroutine RECOVR is not available.

CRIPLE

This subroutine calculates the crippling stress of a panel stiffener using non-dimensional crippling curves.

CRIPRP

This subroutine calculates the section properties of the stiffened panel configurations, including effective skin if flagged.

CRITIC

This subroutine solves for the critical crack length for an infinitely wide plate.

CRKDAT

This subroutine fills the stress intensity factor array and the stiffener load concentration factor array for the case of riveted stiffeners.

CRKSIZ

This subroutine fills the stress intensity factor correction factor array for the case of integral stiffeners.

CUBE

This subroutine fits a cubic polynomial to four points and finds the minimum value. The minimum found is compared with the minimum found on the previous call. If they agree within tolerance then the convergence flag is set. This routine is used by the one dimension search subroutine ONED.

EFFSKN

This subroutine computes the effective width of skin acting with a stiffener. The skin and stiffener materials may be different.

EVA

This subroutine evaluates the overall acceptability of a structural element based on manufacturing constraints and stress analysis.

EVAG

This subroutine is called by REDSON. It determines the flaw growth margin of safety for each element in a symmetry group.

EVAL

This subroutine returns the margin of safety for fatigue.

EVAR

This subroutine is called by REDSON. It determines the residual strength margin of safety for each element in a symmetry group.

FATTB1, FATTB2, FATTB3

These BLOCK DATA subroutines store fatigue data in the form of constant-life diagrams.

FATTIN

This program reads a set of S-N data from input cards or loads a set from FATTAB.

FLTGRO

This subroutine performs the integration of the crack growth per flight rate equation and stores the data for output.

FMDIN

This program sets the values of the fracture mechanics parameters AC, AM, AP, and AKC either from input or from storage. The stored data is set by MATTAB and is contained in FMDAT of common block MATT1.

FMOUT

This subroutine outputs the results of the fatigue, flaw growth, and residual strength analyses.

FMTAB

This BLOCK DATA subroutine stores flaw growth material properties used in the Erdogan flaw growth equation.

FRAME

This program sizes a frame based on Shanley criteria and minimum gage constraints.

FUN

This subroutine produces the gradient of the objective function being minimized at a given design point for use by the nonlinear math programming subroutine MINI.

GEOSTA

This program computes specific station geometry.

GETMS

This subroutine computes the margins of safety for static loads for stiffened panels.

GETN

This subroutine uses a linear-biquadratic interpolation scheme to find cycles to failure given applied stress level and stress ratio - SIGMIN/SIGMAX from a set of S-N data in the form of constant life diagrams.

GETS

This subroutine uses a linear-biquadratic interpolation scheme to find applied stress level given stress ratio - SIGMIN/SIGMAX and cycles to failure from a set of S-N data in the form of constant life diagrams.

GETSTA

This subroutine finds the next station to be optimized based on input information.

GINPT1

This program is called by the input control subroutine INCON. It is used to read in the fuselage or aerodynamic surface basic geometry.

GINPT2
GINPT3
GINPT4

These are dummy programs which are reserved for future alternate geometry input schemes.

GROCON

This subroutine determines the constant and 1 G alternating stresses for each segment of the spectrum. It also calls the equivalent spectrum stress routine and the flaw growth integration routine.

GSIDE

This subroutine determines the constraint function for manufacturing constraints such as minimum gage and maximum stiffener height, etc.

HEADER

This program prints the APAS-IV fanfare.

HSIG

This subroutine computes the hoop stress distribution due to internal pressure between adjacent frames.

IFRM

This subroutine computes the section properties of a typical transport channel or I-section frame. A tear-stopper inside the skin is included with the frame for calculating section properties.

INCON

This is an input control program. This subroutine calls routines as required to read input data.

INDEX

This subroutine determines the indices of the active design variables for a structural element.

INSTIP

This subroutine converts a set of design variables into a set of detail geometry dimensions. This routine acts as an interpreter between the math programming routine and the structural analysis routine.

INTERP

This subroutine performs linear interpolation.

LDLN1

This program is called by the input control subroutine INCON. It is used to read the fuselage or aerodynamic surface external loads.

LDLN2
LDLN3
LDLN4

These are dummy programs which are reserved for future alternate external load input schemes.

LIFE

This program reads the design criteria for fatigue, flaw growth, and damage tolerance requirements.

LINK

This subroutine calls an input routine which reads the information needed to set up the element symmetry groups. It then creates arrays of symmetry indices.

LINKED

This subroutine finds all of the members of a given symmetry group.

LINKIN

This subroutine reads symmetry group information used by LINK.

LOADS

This program determines the externally applied loads at a given station by linear interpolation of input loads.

LOADZ

This subroutine determines the externally applied loads at a given station by linear interpolation of input loads.

LOCALD

This subroutine calculates the load intensities and shear flows applied to the structural elements. These applied internal loads are based on the results of subroutine BOXLDS and the applied external loads from subroutine LOADS.

LOCATE

This subroutine locates the position of a given station within the stored geometry data array. It then determines the required interpolation parameters needed to extract the station geometry information.

LOCBUK

This subroutine evaluates the critical buckling strain for the stiffened panel sub-elements.

LOCOPT

This subroutine controls the local design of each symmetry group. It sets up the input required by the math programming subroutines and interprets the results.

MARGIN

This subroutine calculates the margins of safety of composite panels using an ultimate fiber strain criteria.

MATIN

This program reads the material property input data.

MATTAB

This BLOCK DATA subroutine stores the library of material properties.

MINI

This subroutine modifies the structural design of an element to maximize the margin of safety. The method of Davidon-Fletcher-Powell is used.

MODL1

This subroutine performs the stress analysis of spar-caps and longerons.

NEWTE

This subroutine predicts the cross-sectional area of a structural element necessary to produce a zero margin of safety.

NISHEL

This program initializes the variables used by the internal loads analysis routines.

OFUN

This subroutine is called from ONED during the one dimensional search. It calls FUN to evaluate various designs.

ONED

This subroutine is called from MINI. It obtains the interval in which a minimum lies and performs a one-dimensional minimization.

OPTCON

This program is the optimization control routine. It does an analysis of one structural element or symmetry group at a time until all elements at a given cross-section are optimized.

PANPRP

This subroutine computes the material properties of a layered composite laminate.

POEDAT

This subroutine interpolates from the data stored in POET1 to produce the arrays needed by CRKDAT.

POETB1

This BLOCK DATA subroutine stores stress intensity factor correction factors and stiffener load concentration factors for cracked panels with riveted stiffeners.

PREGRO

This subroutine performs the cycle-by-cycle crack growth analysis and controls the crack life analysis process.

PRODAM

This subroutine does a Miner's rule cumulative damage analysis and returns the total damage and a margin of safety in fatigue.

PROFLT

This subroutine, based on user directives, either extracts a flight spectrum from PROTAB or PROTB2, reads modification data to these spectra, or reads a complete new spectrum from the input data file.

PROTAB

This subroutine stores a typical fatigue spectrum for transport aircraft.

PROTB2

This subroutine stores a typical fatigue spectrum for a light-weight air-to-air fighter.

PRPMAT

This program defines the material properties used during the analysis for each of the applied loading conditions at the temperature indicated for the loading condition.

QUAFIT

This subroutine takes three values from vector of X and vector of Y starting at first coordination point and fits a quadratic equation through the three points and returns the value Y evaluated from the equation X.

RANFIL

This subroutine manipulates a random access disk file. It may be used to open, read, or write on the file.

RDCMR

This is a dummy subroutine which may be replaced or removed from the program if it is available at the user's installation.

If the program is available at the user's installation, the program will read the control point area for the job and enable the subroutine TIMIT to keep track of peripheral processor time and monitor requests.

RECFAT

This program controls the station cross-section redesign process. This process attempts to minimize the station cross-sectional area by adjusting the thickness variables so as to meet the constraints.

RECGRO

This program controls the flaw growth analysis and resizing procedure when flaw growth is critical. It calls REDSON to do the analysis and NEWTE to do the resizing.

RECOVR

This is a dummy subroutine which may be replaced or removed from the program if it is available at the user's installation.

If the program is available at the user's installation, the program will allow recovery in the event of a CP time limit, and subroutine CPLIM will be executed.

RECRES

This program controls the residual strength analysis and resizing procedure when residual strength is critical. It calls REDSON to do the analysis and NEWTE to do the resizing.

REDCON

This program controls the resizing process. It calls the subroutines which add or subtract material from the structural elements in an attempt to produce a minimum weight structure.

REDOPT

This program produces an optimized cross-section at a station.

REDSON

This subroutine finds the critical margin of safety for each symmetry group and stores them.

RESID

This subroutine determines the residual strength of a panel for a given crack size and number of broken stiffeners.

RIB

This program synthesizes an aerodynamic surface rib.

RLIN

This is a multiple purpose linear interpolation routine.

RUNWT

This subroutine calculates the running weights for panels, webs, and sparcaps or longerons at a station.

SAVBT

This subroutine saves the B variables and T variables to be used as end points in the summary output interpolation.

SECMOD

This subroutine calculates the secant modulus at a point on the stress-strain curve, given the strain and the three Ramberg-Osgood parameters.

SECPRP

This subroutine computes the section properties for a one, two or three cell box beam.

SETPRO

This subroutine transfers the material properties of advanced composite materials into the local analysis variables.

SIGBAR

This subroutine determines the equivalent stress "SBAR" and the maximum stress "SMAX" for a given stress spectrum.

SKNSTF

This subroutine computes the compression strength of dual material stiffened panels.

SMINTP

This subroutine interpolates for stations which were not synthesized. Results for the interpolated stations are printed by subroutine SUMOUT

SORT

This routine sorts the elements in a given vector in ascending order. This is a COMPASS routine.

SPECLD

This subroutine calculates the load intensities and shear flows applied to the structural elements. These applied internal loads are based on the results of subroutine BOXLDS and the applied external fatigue spectrum.

STAGE

This subroutine sets up station geometry when a new station is to be sized.

STAOUT

This program prints results at the end of each station optimization.

STATION

This program retrieves data from the data bank for the desired station.

STORE

This subroutine stores station output information and interpolates for stations not sized. It also calculates weights for panels, interior webs and spar-caps or longerons.

SUBIN1

This subroutine is called by the geometry input program GINPT1 to read symmetry group input data.

SUBIN2

This subroutine is called by the geometry input program GINPT1 to read rib/frame input data.

SUMOUT

This program is not currently in use. It is to be used to output the summary information collected by STORE.

TCON

This subroutine initializes the geometry variables used by the analysis routines.

TIMIT

This subroutine logs the central processor time, peripheral processor time, monitor requests, and subroutine calls for multiple calls to multiple subroutines. If subroutine RDCMR is not available, TIMIT will not keep track of peripheral processor time or monitor requests.

TRP2

This subroutine interpolates from the data stored in BF to produce backface correction factors for part through cracks (currently inoperative).

WEB1

This subroutine translates the optimization variables into detail geometry variables and vice-versa. It is used for internal web elements.

WEB2

This subroutine performs stress analysis on internal shear web elements.

XTOV

This subroutine is called by OPTCON (entry VTOX) to convert design variables V into optimization variables X. It is also called by EVA to convert optimization variables supplied by the math programming routine into design variables.

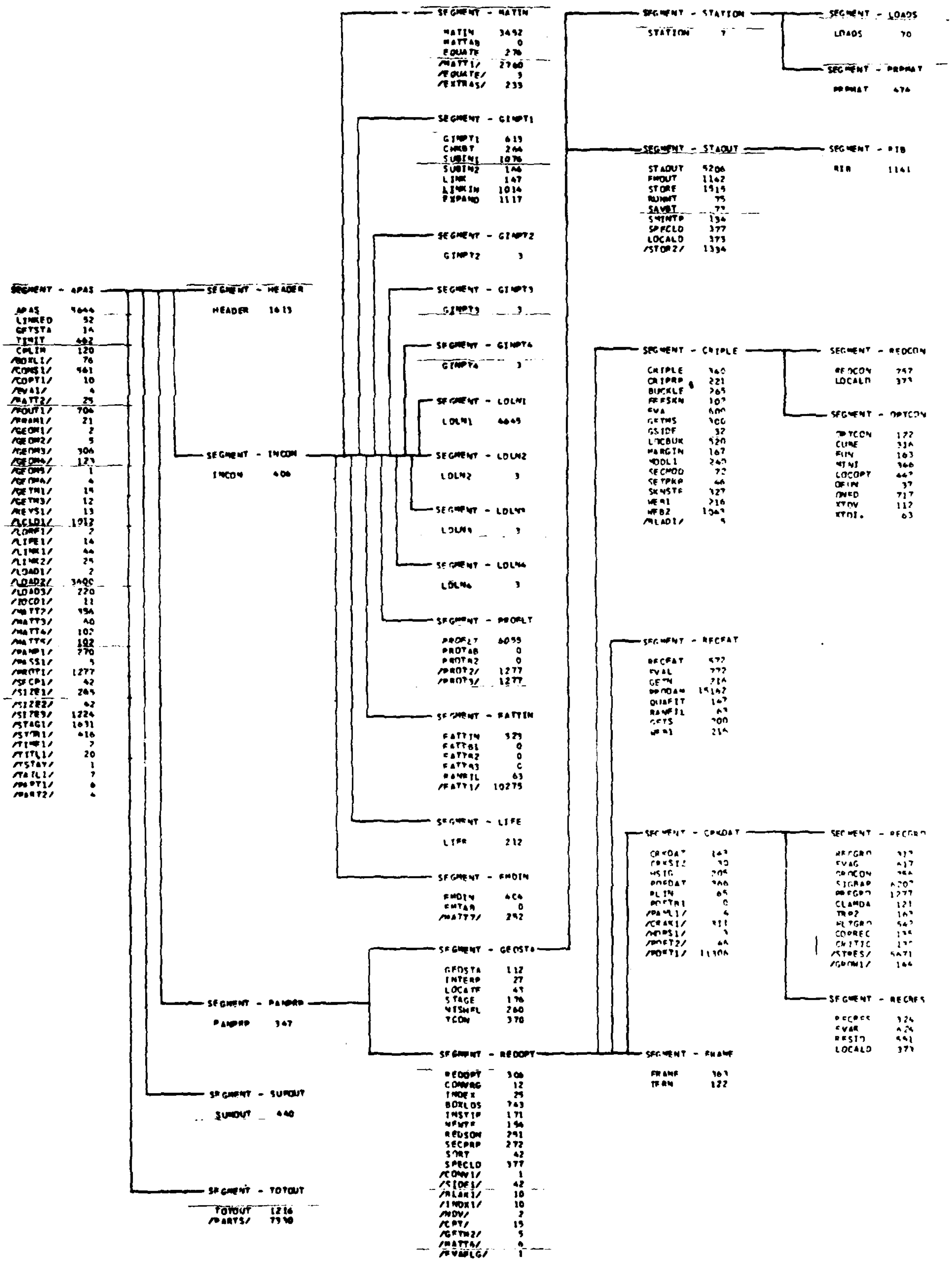

Figure 3-1. APAS IV Segmentation Tree Structure

SECTION IV

USAGE INSTRUCTIONS

4.1 PREPARATION OF INPUTS

4.1.1 FORMAT AND CONTENT. The input variables to the APAS program are entered using the NAMELIST utility. A complete list of the required inputs is presented in the following section.

4.1.2 DESCRIPTION OF INPUT VARIABLES. The input data for the APAS routine is defined in Table 4-1. The charts identify the variable names, descriptions, and units. The variables are grouped under their appropriate NAMELIST input headings.

TITLE	(2 LINES)
$INCN	
$MATIN	(1 SET FOR EACH USER-DEFINED MATERIAL)
$LIF	
$SPEC	(OPTIONAL, INPUT ONLY IF IN $LIF, IDPROC - 1 OR 2)
$FMDM	
$GINPT	
$PARTS	
$LNK	
$LINKN	(1 SET FOR EACH CATEGORY; I.E., PANELS, INTERIOR WEBS, STIFFENERS, OR LONGERONS)
$SUBIN1	(1 SET FOR EACH CATEGORY; I.E., PANELS INTERIOR WEBS, STIFFENERS, OR LONGERONS)
$SUBN2	
ALPHANUMERIC LOAD TITLES	(1 FOR EACH CONDITION. MUST HAVE 12 LINES)
$LDLN	

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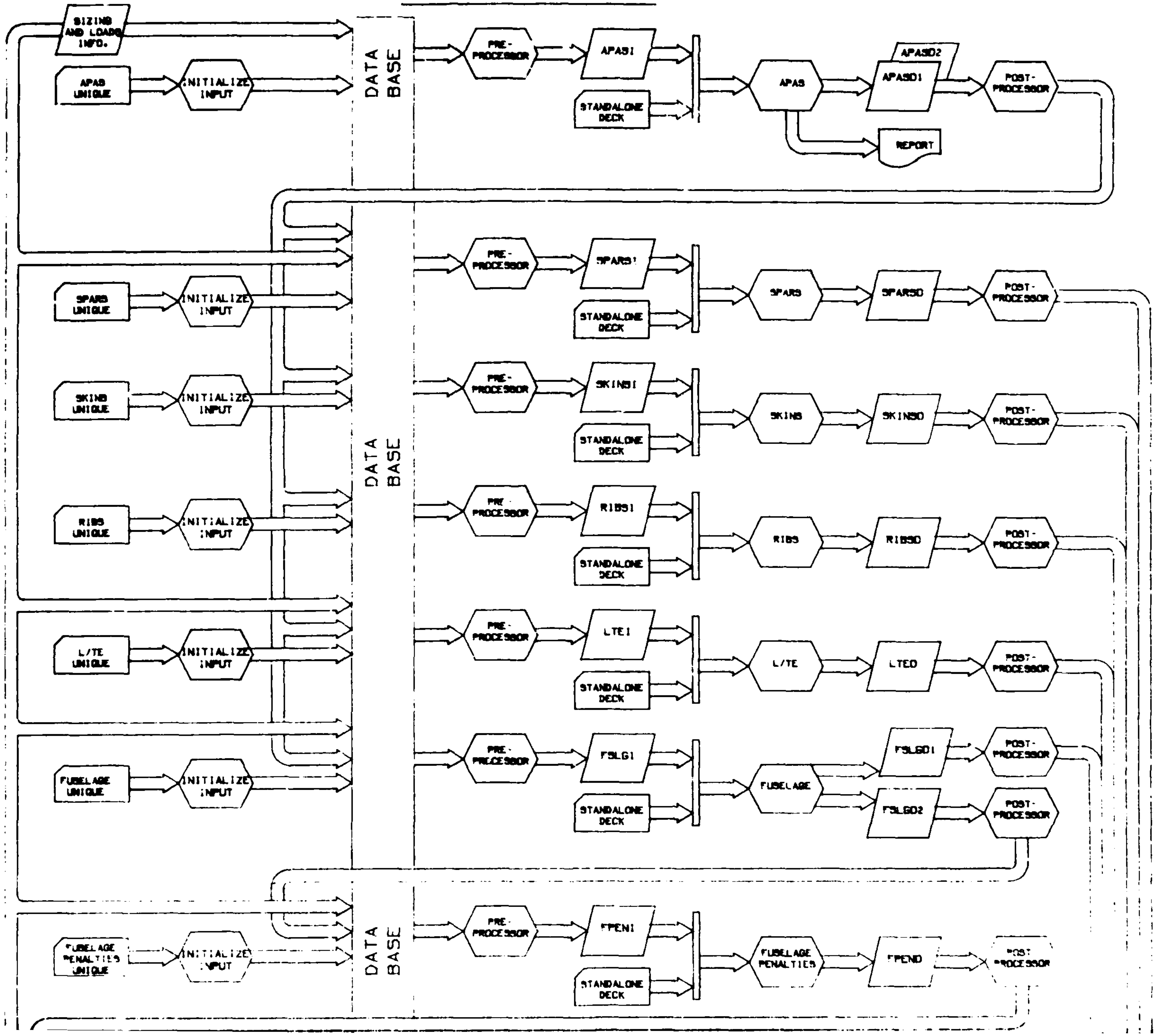
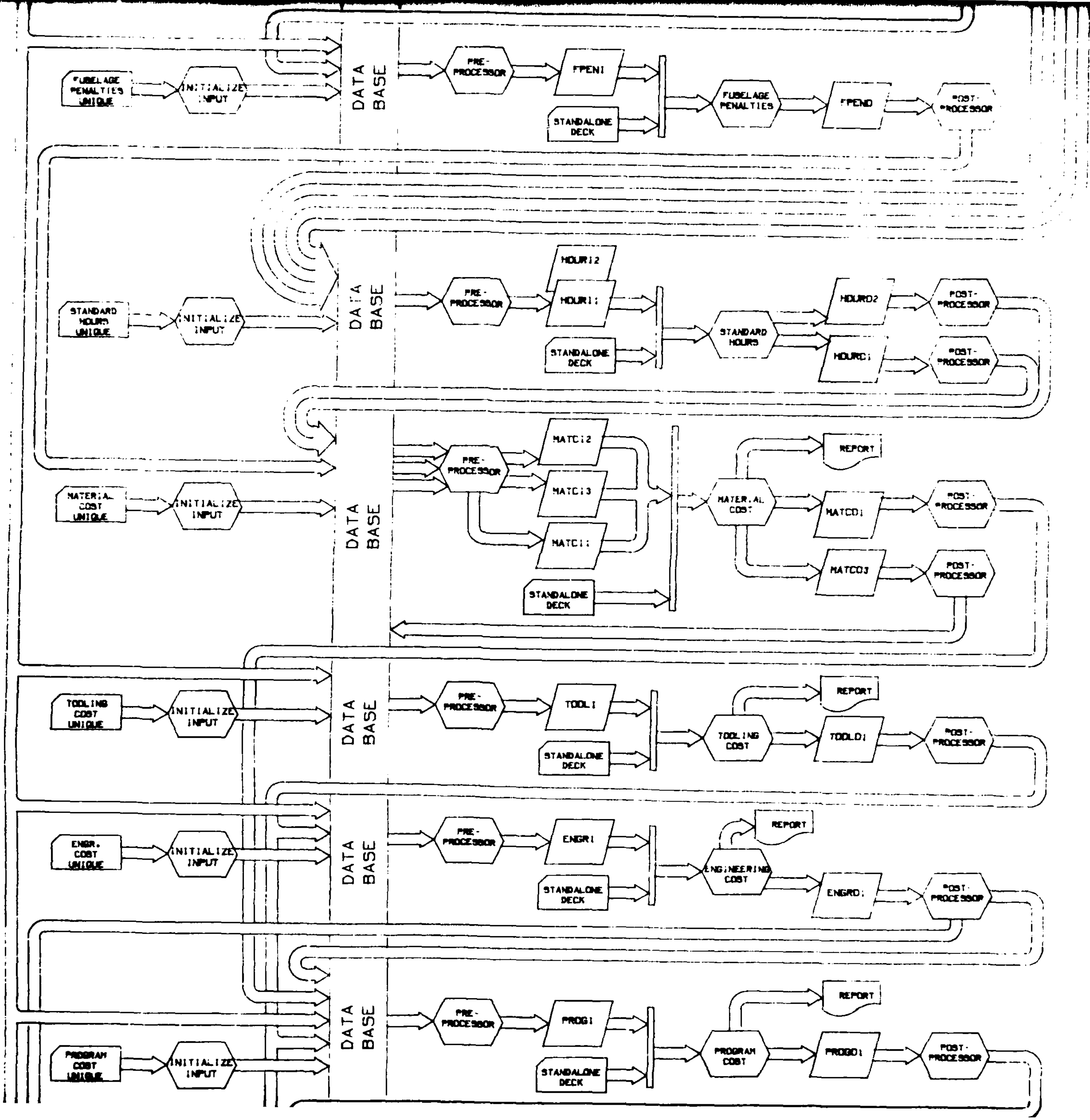



FUSELAGE PENALTIES UNIQUE
INITIALIZE INPUT
DATA BASE
PRE-PROCESSOR
FPEN1
STANDALONE DECK
FUSELAGE PENALTIES
FPEND
POST-PROCESSOR
STANDARD HOURS UNIQUE
INITIALIZE INPUT
DATA BASE
PRE-PROCESSOR
HOURI2
HOURI1
STANDALONE DECK
STANDARD HOURS
HOURO2
HOURO1
POST-PROCESSOR
POST-PROCESSOR
MATERIAL COST UNIQUE
INITIALIZE INPUT
DATA BASE
PRE-PROCESSOR
MATCI2
MATCI3
MATCI1
STANDALONE DECK
MATERIAL COST
REPORT
MATCO1
MATCO3
POST-PROCESSOR
POST-PROCESSOR
TOOLING COST UNIQUE
INITIALIZE INPUT
DATA BASE
PRE-PROCESSOR
TOOLI
STANDALONE DECK
TOOLING COST
REPORT
TOOLO1
POST-PROCESSOR
ENGR. COST UNIQUE
INITIALIZE INPUT
DATA BASE
PRE-PROCESSOR
ENGRI
STANDALONE DECK
ENGINEERING COST
REPORT
ENGRO1
POST-PROCESSOR
PROGRAM COST UNIQUE
INITIALIZE INPUT
DATA BASE
PRE-PROCESSOR
PROGI
STANDALONE DECK
PROGRAM COST
REPORT
PROGO1
POST-PROCESSOR

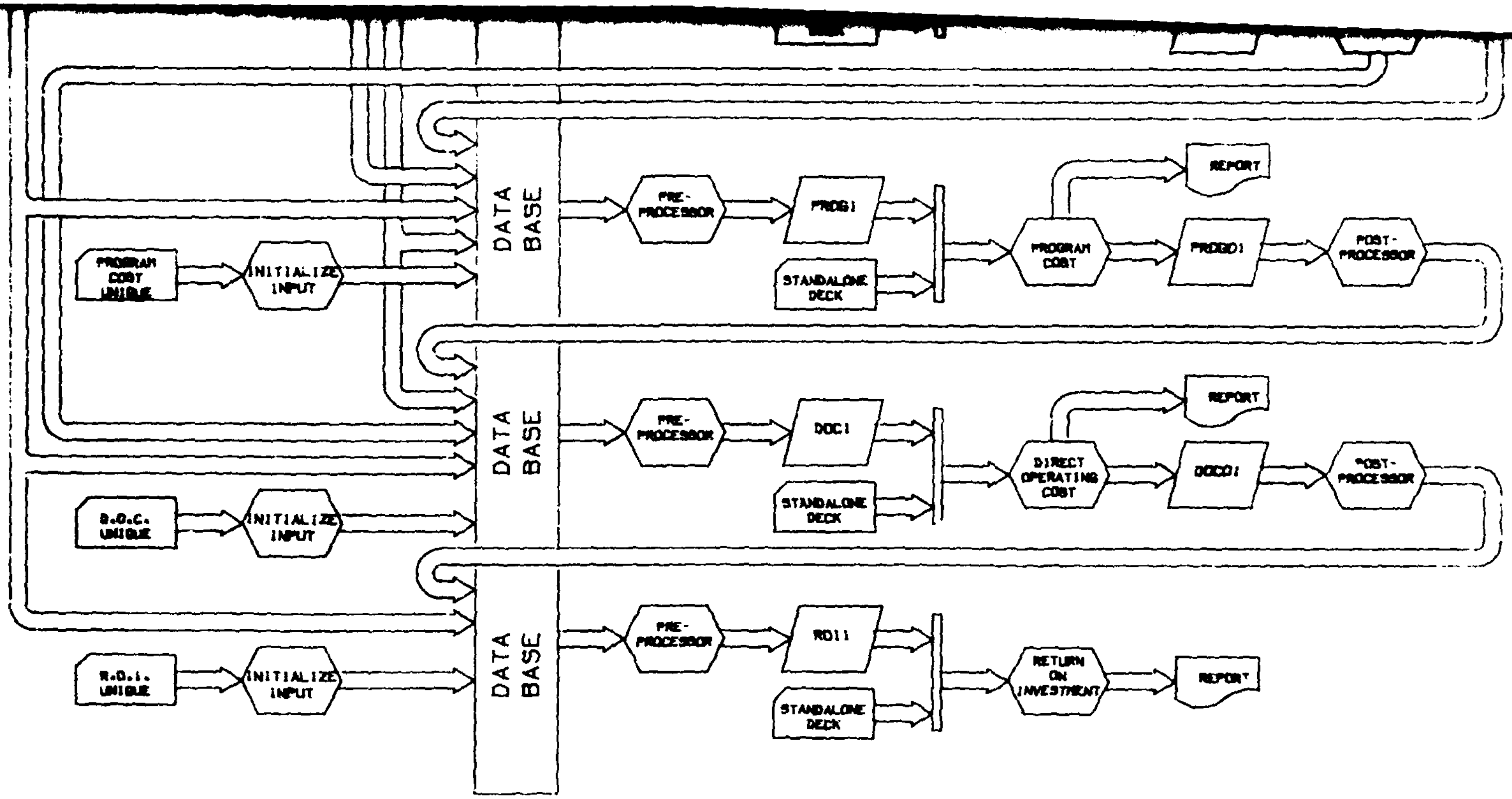


Figure 4-1. Intermodule Data Flow

INPUT DATA CARDS

Description: Title Cards (2 cards)

Format: 8A10

Column:

1	80
TITLE(1) through TITLE(8)	

1	80
TITLE(9) through TITLE(16)	

Field	Contents
TITLE(I), I=1, 16	Any alphanumeric information which the user desires to input for problem identification

INPUT DATA CARD

Description: User Supplied Metallic Material Title Card.

Format: 8A10

Column: 1 ... 80

TYPMAT(1) through TYPMAT(8)

Field	Contents
TYPMAT(I), I = 1, 8	Alphanumeric information describing a metallic material to be input by the user.

Remarks:

1. These cards will be repeated once for each user defined metallic material.

INPUT DATA CARD

Description: Load Condition Header Card

Format: 4A10, I5, 5X, F10.0

Column	1 – 40	41 – 45		51 – 60
	TITCON(1) . . . TITCON(4)	NSTAY		PRESS

Field	Contents
TITCON	Condition title, up to 40 characters
NSTAY	Number of stations at which the load case is defined (20 max)
PRESS	Internal pressure used for fuselage structures, Δ psi

TABLE 4-1. INPUT DATA FOR

PROGRAM: APAS IV

NAMELIST NAME: (FORMATTED) FILE NAME: APAS I·
(Titles and Alphanumeric Information)

SYMBOL	DESCRIPTION	SOURCE
TITLE(16)	Alphanumeric Information for Problem Identification*	UNIQ
TYPMAT (10,20)	Alphanumeric Information Describing a Material to be Input by User**	
TITCON (4,12)	Load Condition Title**	UNIQ
	*Located at beginning of input deck. ** Located before appropriate input NAMELISTS	

TABLE 4-2. INPUT DATA FOR

PROGRAM: APAS IV

NAMELIST NAME: $INCN (Iteration, Tolerance, and Case Control) FILE NAME: APAS I

SYMBOL	DESCRIPTION	SOURCE
IT1	Iteration Count Limit on overall Redesign/Optimization Procedure (Default Value is 5)	UNIQ
IT2	Iteration Count Limit on fully Stressed Redesign Process (Default is 20)	
IT3	Iteration Count Limit on Fletcher Powell Optimization Procedure (Default is 5)	
IT4	Iteration Count Limit for Fatigue Flaw Growth, and Residual Strength Redesign Process (Default is 5)	
EPS1	Tolerance on Redesign Margins of Safety for each Redesign Cycle (Default is 0.001)	
EPS2	Tolerance on Final Margins of Safety at least one Non-minimum Gage Element of each Symmetry group for at least one load condition will have a margin of safety which satisfies MS EPS2 (Default is 0.01)	
EPS3	Tolerance on Optimization Function Decrease in Fletcher Powell Minimization Technique (Default is .001)	
EPS4	Tolerance on Design Variable Variation in Fletcher Powell Minimization Technique (Default is 0.001)	
KEY1	Specifies one of Four Geometry input subroutines = 1, specifies general input subroutine "GINPT1" =2, 3, 4 - not currently available	
KEY2	Specifies one of four external loads definition subroutines = 1 specifies subroutine "LDLN1" =2, 3, 4 - not currently available	
KEY3	Specifies synthesis of wing-like or fuselage type structures = 0, for fuselage type structures = 1, for wing-like structures	
KEY4	Specifies number of locations along structure to be synthesized = 1, synthesize at every rib/frame = 2, synthesize at every second rib/frame, etc., (maximum value is 50)	
KEY5	Analysis/Optimization flag = 0, perform optimization = 1, perform analysis of structure as input, do not perform optimization	
KEY6	Input check flag = 0, normal mode = 1, check input and quit	UNIQ

TABLE 4-2. INPUT DATA FOR

PROGRAM: APAS IV

NAMELIST NAME: $INCN (Cont.) FILE NAME: APAS I

SYMBOL	DESCRIPTION	SOURCE
KEY7	Fatigue analysis flag = 0, no fatigue analysis = 1, include redesign to respect fatigue criteria	UNIQ
KEY8	Flaw growth flag = 0, no flaw growth analysis = 1, include redesign to respect flaw growth criteria	
KEY9	Residual strength flag = 0, no residual strength analysis = 1, include redesign to respect residual strength criteria	
KEY10	CP time limit recovery procedure flag = 0, use normal exist procedure = 1, print output values at time of time limit	
KEY11	Objective function derivative specification flag = 0, central difference derivatives = 1, one sided derivatives (recommended value)	UNIQ

TABLE 4-2. INPUT DATA FOR

PROGRAM: APAS IV

NAMELIST NAME: $MATIN FILE NAME: APAS I

SYMBOL	DESCRIPTION	SOURCE
	(Material specification. Allows the User to select one of the materials built into the program or to specify a material of his own.)	
NMAT	Number of materials to be used	UNIQ
MATID(6)	Identification number for materials to be used:	UNIQ
	<u>ID</u> <u>Material Type</u>	
	1 - 3 User defined metallic material	
	4 AL-2024-T62	
	5 AL-2024-T851	
	6 AL-7075-T6	
	7 AL-2219-T87	
	8 TI-6AL-4V	
	9 TI-8AL-1MO-1V	
	10 Inconel 718	
	11 Inconel 625	
	12 RENE' 41	
	13 - 15 User defined composite	
	16 NARMCO 5505	
	17 NARMCO 5206	

TABLE 4-3. INPUT DATA FOR

PROGRAM: APAS IV

NAMELIST NAME: $MATIN FILE NAME: APASI

VARIABLE	DESCRIPTION	Units	Data
FTEN	Knockdown factor applied to metallic material FTU to obtain the allowable tensile stress for limit load conditions	dimensionless	0.66
NTEMP	Number of temperatures for which a user defined metallic material will have temperature factors input	integer	10
FTU	Ultimate tensile strength	psi	60000.0
EC	Modulus of elasticity in compression	psi	10.5E6
FCY	Compressive yield strength	psi	40000.0
FSU	Ultimate shear strength	psi	30000.0
E	Modulus of elasticity in tension	psi	10.3E6
G	Shear modulue	psi	3.8E6
RHO	Density	lb/in^3	0.10
FO7	Stress from intersection of stress-strain curve with a secant of slope O.7E a Ramberg-Osgood parameter	psi	53000.0
EN	Ramberg-Osgood shape parameter for the stress-strain curve - dimensionless	dimensionless	18.5
TEMPM(9)	Temperature at which material properties are being defined	°F	200.0
FFTU(9)	Factor applied to the FTU at room temperature to obtain the FTU at the corresponding temperature TEMPM(I)	dimensionless	0.75
FFCY(9)	Factor applied to FCY at room temperature to obtain FCY at corresponding temperature TEMPM(I)	dimensionless	0.75
FFSU(9)	Factor applied to FSU at room temperature to obtain FSU at corresponding temperature TEMPM(I)	dimensionless	0.75
FEC(9)	Factor applied to EC at room temperature to obtain EC at corresponding temperature TEMPM(I)	dimensionless	0.75
FE(9)	Factor applied to E at room temperature to obtain E at corresponding temperature TEMPM(I)	dimensionless	0.75
FG(9)	Factor applied to G at room temperature to obtain G at corresponding temperature TEMPM(I)	dimensionless	0.75
FRHO(9)	Factor applied to RHO at room temperature to obtain RHO at corresponding temperature TEMPM(I)	dimensionless	0.95

TABLE 4-3. INPUT DATA FOR

PROGRAM: APAS IV

NAMELIST NAME: $MATIN FILE NAME: APASI

VARIABLE	DESCRIPTION	Units	Data
FF07(9)	Factor applied to F07 at room temperature to obtain F07 at corresponding temperature TEMPM(I)	dimen-sionless	0.75
FEN(9)	Factor applied to EN at room temperature to obtain EN at corresponding temperature TEMPM(I)	dimen-sionless	0.75

TABLE 4-3. INPUT DATA FOR

PROGRAM: APAS IV

NAMELIST NAME: $MATIN FILE NAME: APASI

VARIABLE	DESCRIPTION	Units	Data
E11	Lamina modulus of elasticity in the fiber direction	psi	40.0E6
E22	Lamina transverse modulus of elasticity	psi	1.5E6
G12	Lamina in-plane shear modulus	psi	4.0E6
U12	Lamina Poisson's ratio for loading in the fiber direction	dimen-sionless	0.20
DEN	Density of composite material	lb/in^3	0.55
EPSAL1	Lamina ultimate allowable tensile strain in the fiber direction	in./in.	7.0E-3
EPSAL2	Lamina ultimate allowable tensile strain in the transverse direction	in./in.	7.0E-3
EPSAL3	Lamina ultimate allowable shear strain	rad.	27.0E-3
EPSAL4	Lamina ultimate allowable compressive strain in the fiber direction	in./in.	11.0E-3
EPSAL5	Lamina ultimate allowable compressive strain in the transverse direction	in./in.	28.0E-3

TABLE 4-4. INPUT DATA FOR

PROGRAM: APAS IV

NAME LIST NAME: $SPEC FILE NAME: APASI

(Spectrum Input Data)

VARIABLE	DESCRIPTION	UNITS	DATA
	(Spectrum modification is required if ID PROC = 1 or 2 in NAMELIST $LIF. If ID PROC = 2, the following variables would describe the fatigue spectrum. One load condition in NAMELIST $LDLN would define the reference fatigue loading condition.)		
NOCYC	Number of load steps in the input stress spectrum	Integer	
EM	Number of flights represented in the input stress spectrum	Real	
FSIG	Factor applied to FKMAX and FKMIN	Real	
FKMAX(1000)	Factor applied to reference fatigue condition stress to obtain maximum spectrum stress for each of NOCYC load steps. Maximum spectrum stress FMAX, based on reference stress SIG, is obtained as follows: FMAX = FKMAX * FSIG * SIG	Real	
FKMIN(1000)	Factor applied to reference fatigue condition stress to obtain minimum spectrum stress for each NOCYC load steps	Real	
CYC(1000)	Number of load cycles for each of NOCYC load steps	Real	

TABLE 4-4 INPUT DATA FOR

PROGRAM: APAS IV

NAME LIST NAME: $SPEC FILE NAME: APASI

(Spectrum Input Data)

VARIABLE	DESCRIPTION	UNITS	DATA
CY(20,20)	Cycles CY(J,I) in the profile for segment I, subsegment I based on CYCBS flights	Real	
FCON(6,20)	Constant stress composition table, FCON(L,I), where the constant stresses for segment I are based on linear combinations of the stresses due to L-spectrum loading conditions. Spectrum loading conditions are: __Cond No.__ __Description__ 1 1 G taxi 2 1 G flight 3 1 G flight + 1 G vertical gust 4 1 G flight - 1 G maneuver 5 1 G landing impact 6 Maximum internal pressure	Real	
FALT(6,20)	Alternating stress composition table, FALT(L,I), where stress excursions for segment I are based on the linear combination of the stresses due to L-spectrum loading conditions. Magnitude of the stress excursions is obtained from linear scaling by the incremental load factor table DG, based on the load-type specification LT.	Real	

TABLE 4-4 INPUT DATA FOR

PROGRAM: APAS IV

NAME LIST NAME: $SPEC FILE NAME: APASI

(Spectrum Input Data)

VARIABLE	DESCRIPTION	UNITS	DATA
	(Spectrum modification is required if ID PROC = 1 or 2 in NAMELIST $LIF. If ID PROC = 1 the following variables may be used to modify stored data.)		
CYCBS	Basis for occurrence data, based on CYCBS flights	Flights	10,000
NOSEG	Number of segments	Integer	20
NOSUB	Number of subsegments	Integer	20
DG(20)	Incremental load factor for each subsegment	Real	
LT(20)	Segment load-type specification describing nature of cycling 1 = maneuver; twice delta G excursion from basic condition 2 = taxi/gust; positive and negative delta G excursion about basic condition 3 = landing impact; twice delta G negative excursion from basic condition	Integer	
IN(20)	Segment environment specification 1 = flight condition 2 = ground condition	Integer	

TABLE 4-5 INPUT DATA FOR

PROGRAM: APAS IV

NAME LIST NAME: $FMDN FILE NAME: APASI

(Fracture Mechanics Material Data)

VARIABLE	DESCRIPTION	UNITS	DATA
IFM(6)	Flag to indicate whether to use stored fracture mechanics material properties data or to input the data 0 = stored data will be used 1 = user inputs data	Integer	
AC(6)	Growth-rate-equation coefficient (c)	Real	1.0E-20
AM(6)	Growth-rate-equation (1-R) exponent (m)	Real	0.6
AN(6)	Growth-rate-equation exponent (n)	Real	3.64
AQ(6)	Acceleration model exponent (q)	Real	0.3
AKC(6)	Plane stress facture toughness	psi $\sqrt{in.}$	9.2E4
AKIC(6)	Plane strain fracture toughness	psi $\sqrt{in.}$	4.5E4
THRESH(6)	Threshold value of Δk at R = 0	psi $\sqrt{in.}$	2.5E3
CUT(6)	Shutoff ratio	Real	3.0
RCUT(6)	Positive stress ratio cut off value	Real	0.75
RCUTN(6)	Negative stress-ratio cutoff	Real	-0.99

TABLE 4-6. INPUT DATA FOR

PROGRAM: APAS IV

NAMELIST NAME: $GINPT FILE NAME: APASI

(Box Beam Geometry Input)

VARIABLE	DESCRIPTION	Units	Data
NODES	Number of node points in a cross section. $3 \leq$ nodes ≤ 20	integer	15
NWEB	Number of interior webs maximum of 3	integer	2
NLONG	Number of spar caps/longerons max of 10	integer	5
NSTAG	Number of geometry control stations max of 20	integer	15
STAG(20)	Station number of control station	in.	100.0
FRSP(20)	Rib/Frame spacing	in.	50.0
XLDRF(20)	X-Coordinate of input loads reference axis	in.	200.0
ZLDRF(20)	Z-Coordinate of input loads reference axis	in.	100.0
GTRX(20)	Taper distance of structure in the X-direction	in.	100.0
GTRZ(20)	Taper distance of structure in the Z-direction	in.	100.0
ITEM(20)	Node number. Begins with 1, numbered clockwise around structure cross-section	integer	15
GX(20,20)	GX(I, J) = X Coordinate of Node J at Station I	in.	100.0
GZ(20,20)	GZ(I, J) = Z Coordinate of Node J at Station I	in.	100.0
IW(6)	IW(1) = Number of the first node to which the first interior web is attached. IW(6) = number of the node to which the other end of the first interior web is attached. IW(2) and IW(5) describe the next interior web, IW(3) and IW(4) describe the last interior web.	integer	2
IL(10)	Node number of spar-cap/longeron I	integer	5
DL(10)	Orientation angle of spar-cap/longeron I	degrees	20.0

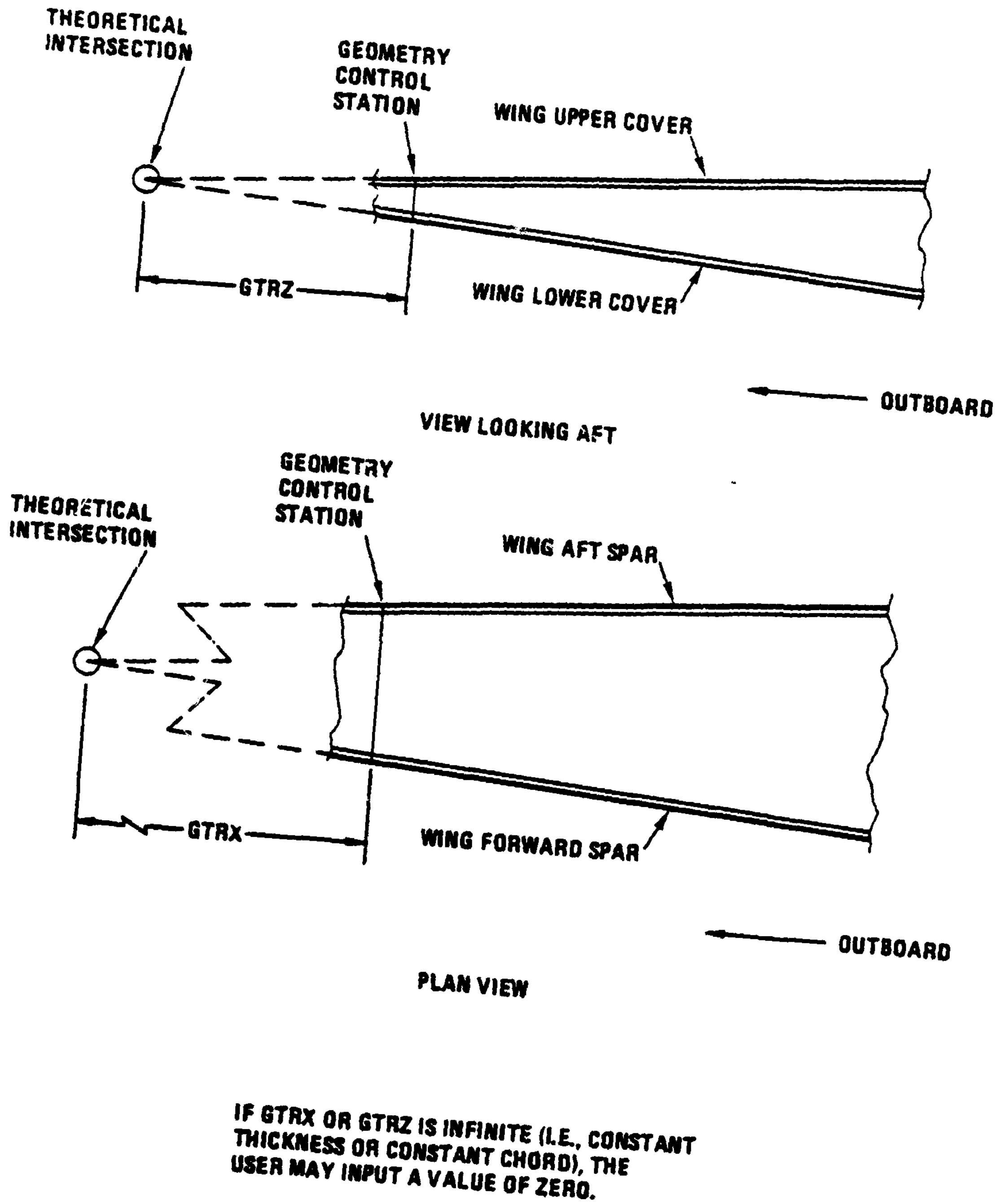


Figure 4-3. Typical Wing Taper Ratio

TABLE 4-7. INPUT DATA FOR

PROGRAM: APAS IV

NAMELIST NAME: $LNK FILE NAME: APASI

(Symmetry Group Control)

VARIABLE	DESCRIPTION	Units	Data
NSGP	Number of panel symmetry groups	integer	5
NSGW	Number of interior web symmetry groups	integer	5
NSGL	Number of sparcap/longeron symmetry groups	integer	5

NSGP	Number of panel symmetry groups
NSGW	Number of interior web symmetry groups
NSGL	Number of sparcap/longeron symmetry groups

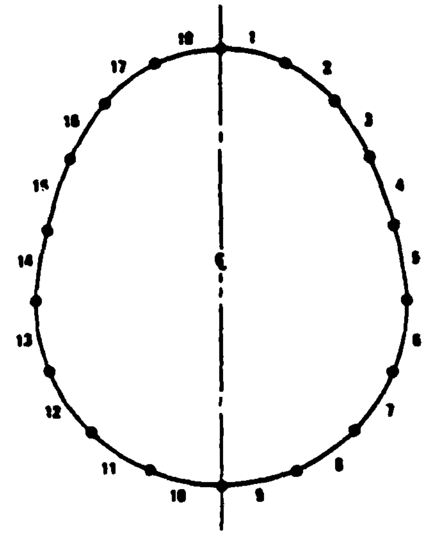
Remarks:

1. The use of symmetry groups is illustrated in Figure 4-4.

2. The following examples illustrate the use of symmetry groups. The first example represents a section cut through the fuselage of a typical transport fuselage. The numbers indicate individual panel elements between adjacent node points. A typical set of symmetry groups is listed below the fuselage section, indicating that four separate designs are desired, one for each group, i.e., panels 1, 2, 3, 16, 17, and 18 will all have the same detailed design dimensions. This design will be dictated by the most critical panel or panels in the group. Note that corresponding panels on opposite sides of the centerline are members of the same symmetry group, (e.g., panels 1 and 18 are members of Group 2). This type of grouping provides for centering symmetry.

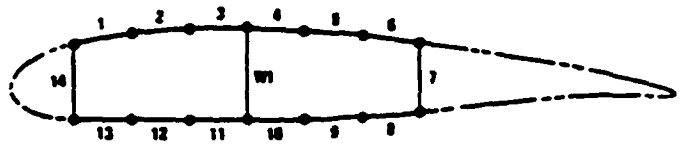
   The second example presents the use of symmetry groups for a wing-type structure. As before, the numbers indicate panel numbers, with the exception of W1, which represents an interior web member. The set of symmetry groups shown below the wing section indicates four symmetry groups. Panels 7, 14, and interior web W1 are not members of any symmetry group for this example and hence will have unique designs. Therefore, a total of seven separate designs will be generated at each cross-section.

A new set of designs for a cross-section is produced at each station where optimization is performed. The symmetry grouping is preserved for the entire length of the structure. Panels of a given symmetry group will have the same design at any given station. However, the design is free to change from station to station.



GROUP NO.	PANELS
1	1, 2, 3, 16, 17, 18
2	4, 5, 14, 15
3	6, 7, 12, 13
4	8, 9, 10, 11

Example 1. Typical Fuselage Section



GROUP NO.	PANELS
1	1, 2, 3
2	4, 5, 6
3	8, 9, 10
4	11, 12, 13

Example 2. Typical Wing Section

Figure 4-4. Structural Symmetry Grouping

TABLE 4-8. INPUT DATA FOR

PROGRAM: APAS IV

NAMELIST NAME: $LINKN FILE NAME: APASI

(Panel Symmetry Group Identification)

VARIABLE	DESCRIPTION	Units	Data
KMAX(20)	KMAX(I) = Number of elements in symmetry Group I	integer	5
NSE(20, 20)	NSE (K, I) = Element number of the Kth element in symmetry Group I NOTE: One LINKIN namelist is input for each symmetry group type - panels, webs, and spar-caps /longerons. Total of 3. Numbering of panels is clockwise around the cross section. Numbering of webs starts with web closest to front spar. Spar-cap/longeron numbers are equal to their corresponding node numbers.	integer	(5,5)

TABLE 4-9. INPUT DATA FOR

PROGRAM: APAS IV

NAMELIST NAME: $SUBIN1 FILE NAME: APASI

(Structural Element Configuration Type Identification)

VARIABLE	DESCRIPTION	Units	Data
ITYPE(20)	Structural configuration type number.	integer	1
IDSET(20)	Unique ID for the corresponding structural element configuration specification.	integer	2
IDMAT1(20)	Material ID of element for riveted panel elements. This is ID of skin only.	integer	2
IDMAT2(20)	Material ID of stiffeners for riveted panel only: ITYP(I) = 4 thru 9.	integer	2
FELEM(20)	Used for panel and web element types 10, 11, and 12 only. Unsupported panel width in terms of a factor times the panel element width.	in.	20.0
T(20, 4)	Initial value for various cross-section thicknesses (T variables).	in.	.04
TMN(20, 4)	Minimum values for T variables.	in.	.04
B(20, 4)	Initial values for various cross-section dimensions (B variables).	in.	10.0
BMN20, 4)	Minimum values for B variables.	in.	5.0
BMX(20, 4)	Maximum values for B variables.	in.	100.0

TABLE 4-10. INPUT DATA FOR

PROGRAM: APAS IV

NAMELIST NAME: $SUBN2 FILE NAME: APASI

(Rib/Frame Configuration Type Identification)

SYMBOL	DESCRIPTION	SOURCE
IFT	Rib/Frame configuration type number Frame = 0, suppress frame analysis = 1,. ring frame with zee cross section Rib = 0, suppress rib analysis = 1, corrugated web = 2, integral web = 3, built-up web = 4, integral truss = 5, built-up truss	UNIQ
IDMTFR	Rib/Frame material ID	UNIQ
IDMTRS	Rib stopper material ID used for fuselage type structures only	UNIQ

TABLE 4-11. INPUT DATA FOR

PROGRAM: APAS IV

NAMELIST NAME: $LDLN (Input Loads Control) FILE NAME: APASI

VARIABLE	DESCRIPTION	Units	Data
NCOND	Number of loading conditions maximum of 6	integer	2
FULT	Ultimate factor of safety	real	1.5
NSPEC	Number of loading conditions in the fatigue and flaw growth spectrum	integer	5
FBUCK	Factor for initial buckling of skin between stiffeners for skin stiffener construction type panels	real	0.50
NSTAY(12)	Number of stations at which load case is defined	integer	10
PRES(12)	Internal pressure used for fuselage structures	psi	15.0
ELIN(12)	Factor applied to STA	real	0.50
FLD(12)	Factor applied to all input load components (temperature excluded)	real	1.5
FA(12)	Factor applied to AX	real	1.5
FXS(12)	Factor applied to XS	real	1.5
FZS(12)	Factor applied to ZS	real	1.5
FTOR(12)	Factor applied to TOR	real	1.5
FXM(12)	Factor applied to XMOM	real	1.5
FZM(12)	Factor applied to XMOM	real	1.5
FTEMP(12)	Factor applied to TEMP	real	1.5
STA(20, 12)	Fraction of fuselage length or wing semi-span	real	0.50
AX(20, 12)	Station axial load	lbs	10000.0
XS(20, 12)	Station X shear force	lbs	10000.0
ZS(20, 12)	Station Z shear force	lbs	10000.0
TOR(20, 12)	Torque	in-lbs	10000.0
XMOM(20, 12)	Bending moment about X-axis	in-lbs	10000.0
ZMOM(20, 12)	Bending moment about Z-axis	in-lbs	10000.0
TEMP(20, 12)	Structural temperature	deg/Fahr	200.0

Figure 4-5 shows a graphical representation of the flow of data into and out of the APAS Structural Synthesis module. The NAMELIST input data is on a file called APASI. This data is retrieved from the data bank by the ADM and preprocessed to the format needed by the skin panel module. The output is stored on files called APASΦ1 and APASΦ2. This output data file is post-processed by the ADM and stored in the data base. The output is discussed in the OUTPUT FORMAT and CONTENT section of this manual.

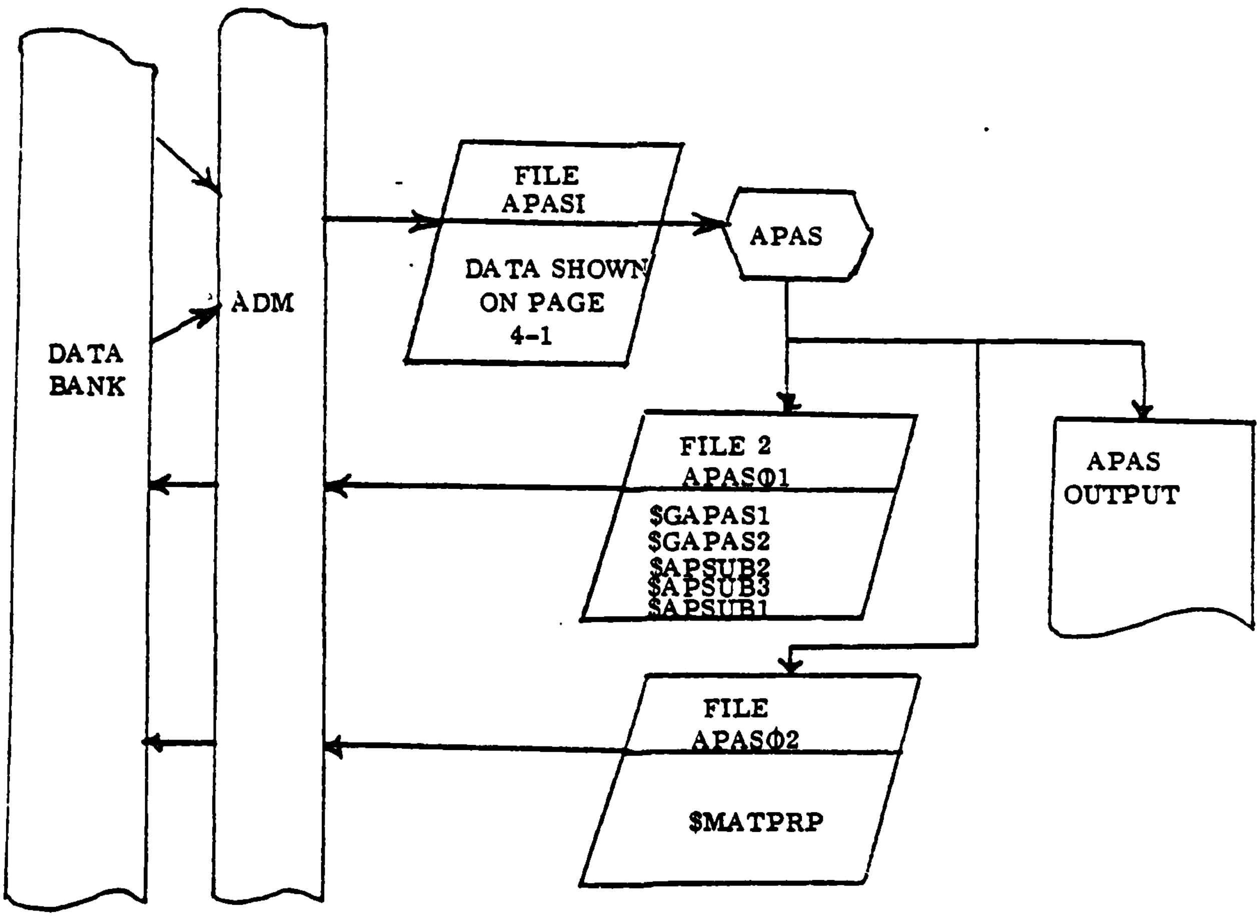


Figure 4-5. APAS - Data Flow

4.1.3 LIMITATIONS AND RESTRICTIONS

The APAS program performs a multi-station structural analysis for sizing of box beam structure elements. A detailed discussion of the analysis procedure and assumptions is presented in the following paragraph.

TECHNICAL DISCUSSION

The technical approach used in APAS IV is applicable to any closed section beam-like structure, and it is typical of the procedure used in the early design phase of aircraft structure. The overall approach makes use of a point design/analysis/redesign process that is iterated until an acceptable design is produced. Figure 2-1 presents the functional flow chart for the approach used in the APAS IV computer program. This flow chart outlines the major analysis and design loops of the program.

This section includes a discussion of each of the following topics: Component Geometry, Structural Elements, Flight Profile and Load Spectrum, External Loads, Structural Design Procedure, and Structural Analysis. The structural analysis discussion includes the static strength, stability, fatigue, fracture, and residual strenght analysis used in APAS IV.

COMPONENT GEOMETRY

The geometry of each component (fuselage, wing, horizontal and vertical stabilizer) is represented by the coordinates of a set of nodes at each of the various stations along the component. This nodal geometry describes the shape of the component used for the computation of section properties and internal loads. The program is capable of reading and storing nodal information at geometry control stations. Storage for 20 control stations is available for nodal information; however, fewer may be used. The program uses linear interpolation between control stations to determine required nodal information. Nodal information at a control station consists of X and Z coordinates for each node. The program provides for a maximum of 20 nodes per control station.

FUSELAGE NODAL GEOMETRY

Nodal geometry for a typical transport fuselage is presented in Figure 4-6. Nodes are numbered starting at the top centerline and proceeding clockwise looking aft.

AERODYNAMIC SURFACE NODAL GEOMETRY. The nodal geometry describes the box structure for an aerodynamic surface with up to five spars. The nodes are numbered beginning at the upper sparcap of the front spar and proceeding clockwise to the lower front sparcap. A typical surface nodal geometry is presented in Figure 4-7.

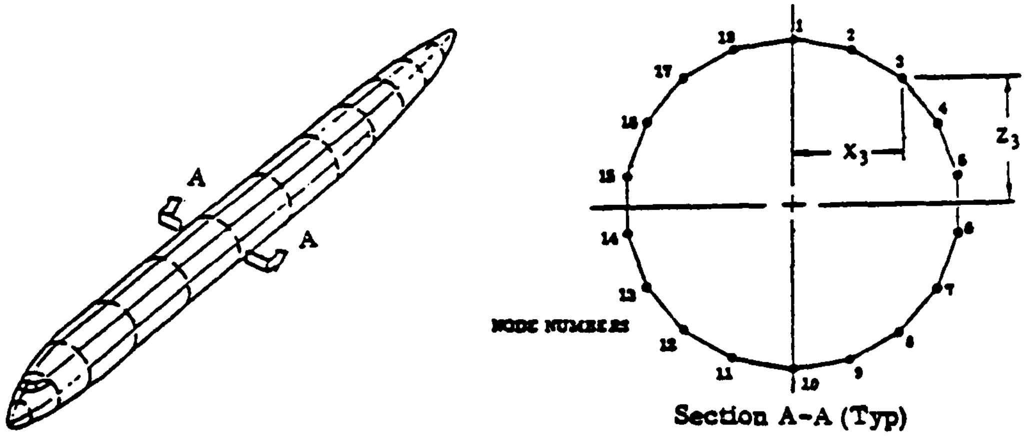


Figure. 4-6. Fuselage Nodal Geometry

STRUCTURAL ELEMENTS, RIBS, AND FRAMES

STRUCTURAL ELEMENTS. Structural elements include skin panels, spar webs, and spar caps. Each element is described by a type number and by from one to eight dimension variables. The dimension variables are of two types, thickness variables and non-thickness variables such as stiffener spacing, stiffener height, and corrugation angle. All variables may have manufacturing constraints imposed. In general, non-thickness variables (i.e., B variables) may be set to a constant value or may be constrained between upper and lower limits. Thickness variables (i.e., T variables) may either be set to a constant value or may have minimum gage constraints imposed. T and B variables are shown for the various construction types in Figures 4-8 through 4-10.

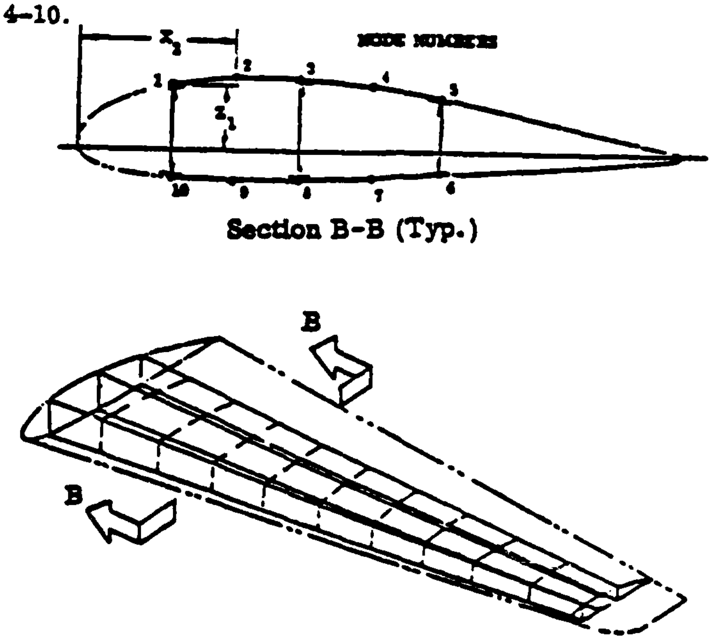


Figure 4-7. Aerodynamic Surface Nodal Geometry

Skin Panel Construction Types. The structural synthesis program includes 12 types of panel elements as presented in Figure 4-8 The stiffeners on panel types one through nine are assumed to be oriented parallel to the elastic axis of the structure. The 0 degree ply of panel type 12 is also assumed to be parallel to the elastic axis.

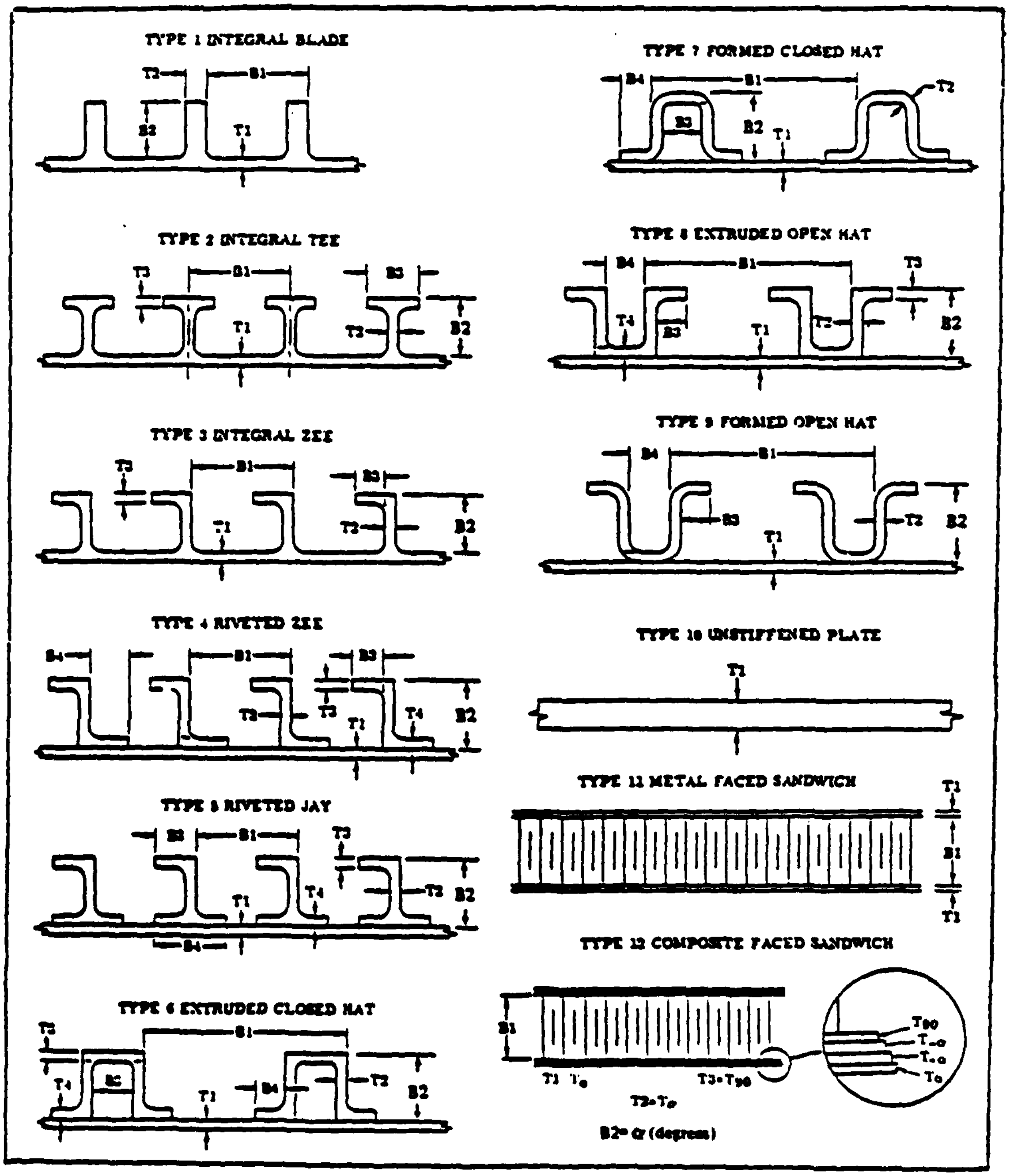


Figure 4-8 Skin Panel Construction Types

"Spar Web" Elements. The structural synthesis program contains seven types of "spar web" elements. Four of these are truss type elements, two are stiffened webs, and the remaining one is a corrugated web. These elements are presented in Figure 4-9. "Spar Web" elements are assumed to resist only shear and crushing loads, the axial stiffness of these elements is assumed to be zero for the purpose of computing section properties.

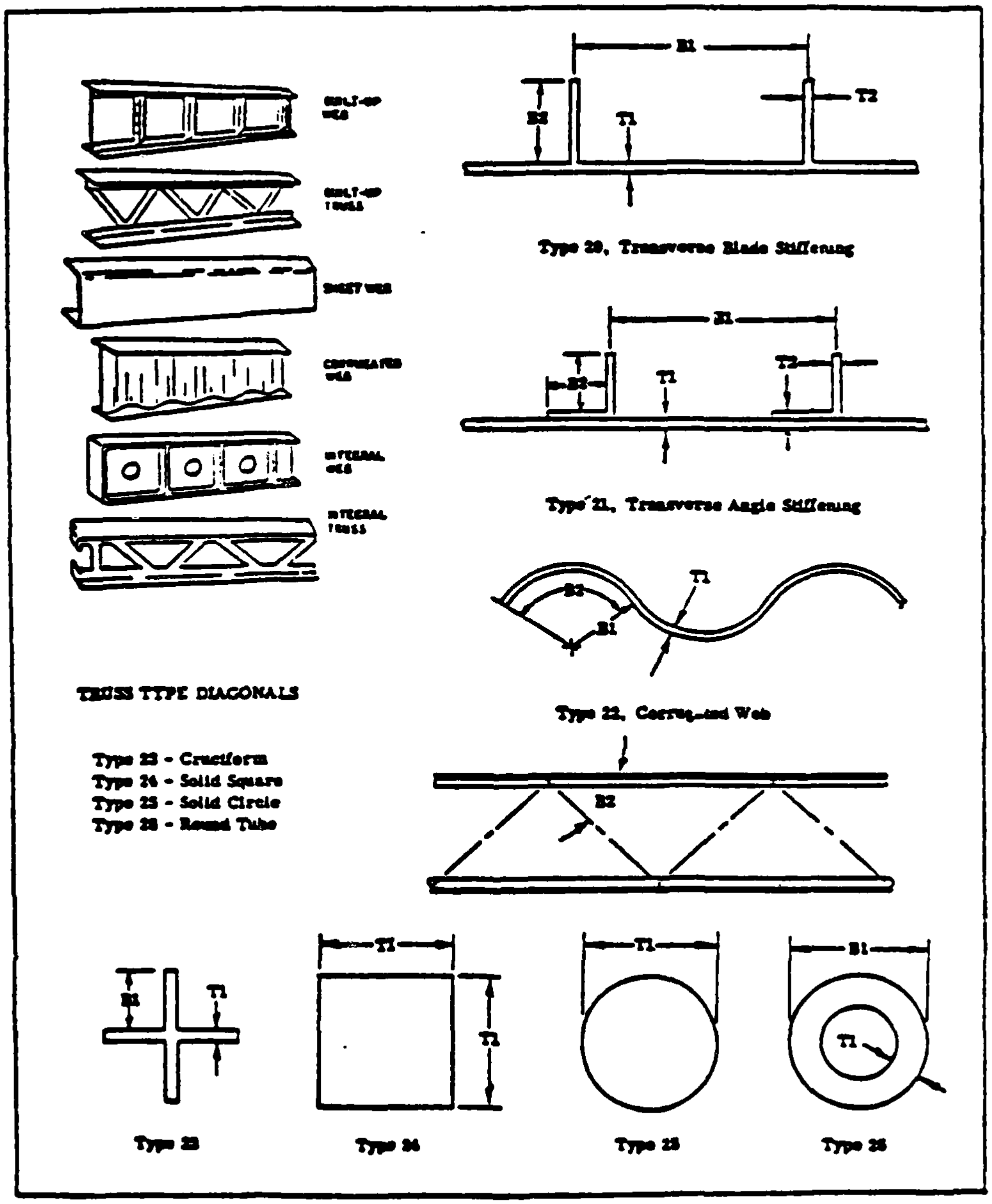


Figure 4-9. Spar Web Elements

Spar Cap Elements. Four types of spar caps are currently available. They include integral tee and angle and riveted tee and angle as shown in Figure 4-10.

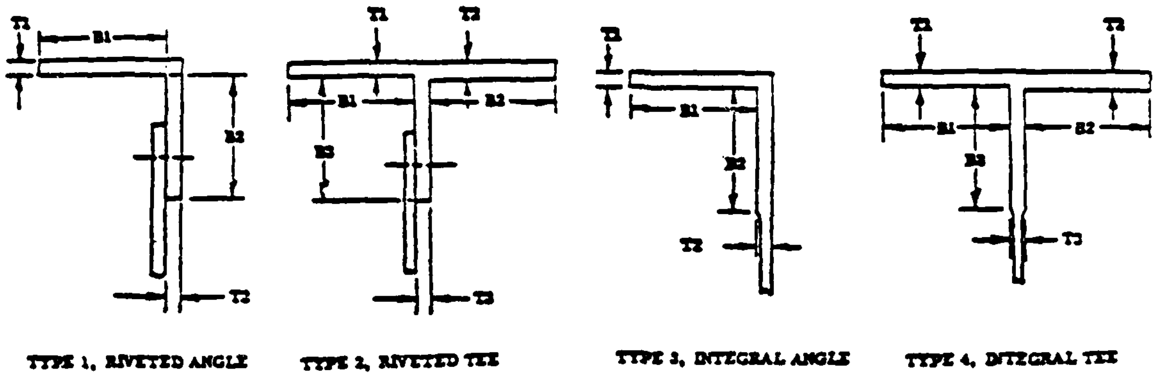


Figure 4-10. Spar Cap Elements

RIBS. The types of ribs available within the program are presented in Figure 4-11. The ribs consist of caps and webs or truss elements. Rib caps are sized to react a moment at the rear spar due to the loading on the surface aft of the rear spar. Rib webs are sized to carry shear and to support crushing loads.

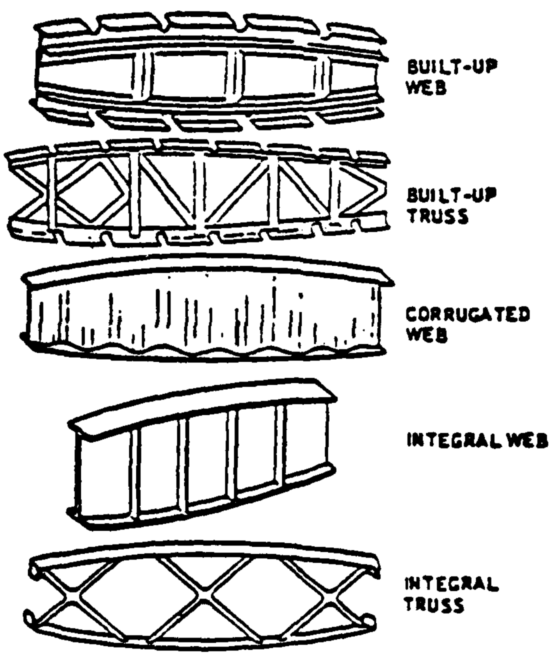


Figure 4-11.

FRAMES. A typical ring frame is shown in Figure 4-12. The frames are sized so that the outer flange clears all of the skin stiffeners. The inner flange is maintained at 14 cm (5.5 inches) from the outer skin contour. The frame is sized using Shanley's criteria to set a minimum frame bending stiffness. The frame is set to minimum gage for non-critical areas.

$$EI = \frac{C_f M D^2}{L}$$ Shanley's criteria (Reference 4)

where:

EI = frame bending stiffness [in^2 - lb.]

M = maximum resultant fuselage bending moment, $\sqrt{M_x^{\,2} + M_z^{\,2}}$ [in.-lb.]

D = fuselage diameter [in.]

L = frame spacing [in.]

C_f = fit coefficient (.00025) [dimensionless]

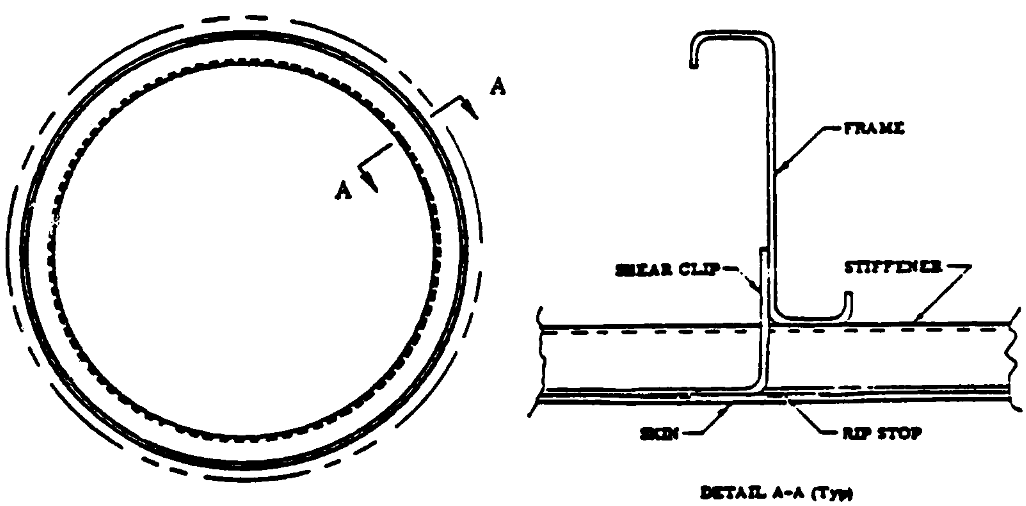


Figure 4-12 Typical Ring Frame

FLIGHT PROFILE AND LOAD SPECTRUM

The fatigue load spectrum defines the number of times that incremental loads of given magnitudes are encountered during the design life of the aircraft. Experimental data is available that defines the probable magnitudes and frequency of occurrence of these incremental loads as a function of aircraft type, configuration parameters, and flight parameters.

The configuration and flight parameters are defined using a typical flight profile, which is divided into segments. Parameters are averaged for each segment, and these average values are used in finding the incremental loads. See Figures 4-13 and 4-14.

Typical flight spectra based on medium range operation of a contemporary transport aircraft and for a light weight air-to-air fighter are currently included in the program library for fatigue and flaw growth analysis.

The parameter values for each transport aircraft flight segment are listed in Table 4-12. The segments are divided into subsegments, with each subsegment representing a particular magnitude of incremental load. Using the segment parameters and the subsegment load, frequency of occurrence of the incremental load is found for each subsegment using the methods and information in Reference 5.

For gust loads, curves showing gust velocity vs frequency of occurrence are found in Reference 5, Figures C13-32 through C13-37. From Reference 5, Page C13 24,

$$\Delta g = mSV_e U_{de} K_g \, \rho_o/(2W)$$

For speeds below critical Mach number:

$$K_g = \frac{.88\mu_g}{5.3 + \mu_g} \qquad \mu_g = \frac{2W}{mgeS\rho}$$

where

Δg = incremental load factor [dimensionless]

m = slope of lift curve [dimensionless]

S = wing area [Ft.^{2}]

V_e = equivalent airspeed [Ft./Sec.]

U_{de} = derived gust velocity [Ft./Sec.]

K_g = gust alleviation factor [dimensionless]

ρ_o = air density at sea level [lb/ft^3]

W = aircraft weight [lb.]

μ_g = aircraft mass ratio [dimensionless]

g = acceleration of gravity [Ft./Sec.^{2}]

c = mean geometric wing chord [Ft.]

ρ = air density [lb./ft.^{3}]

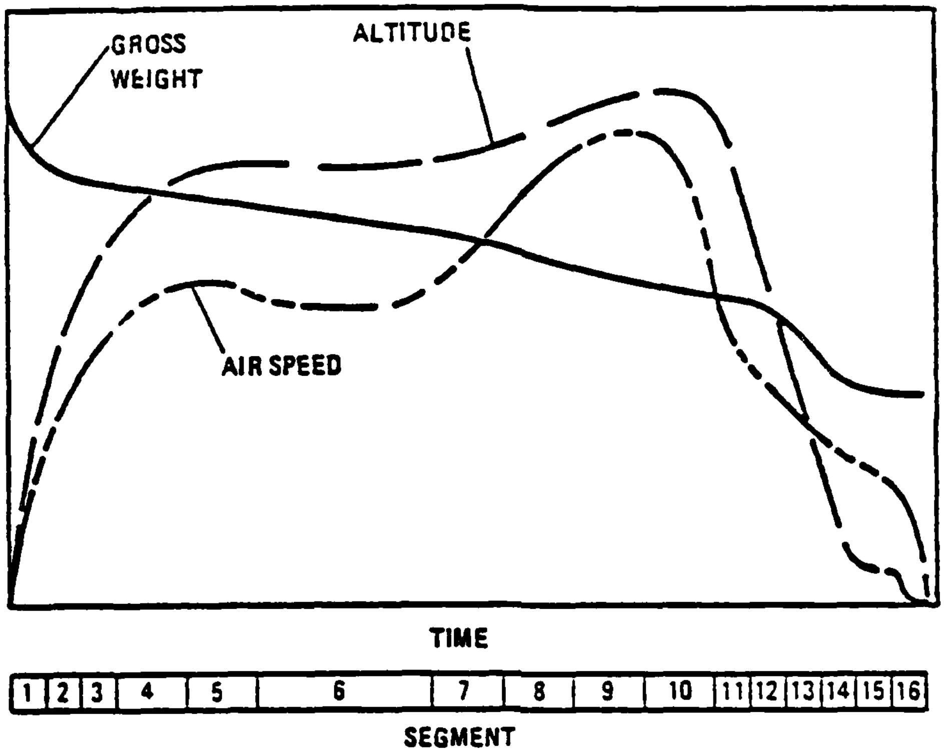


Figure 4-13. Typical Flight Profile

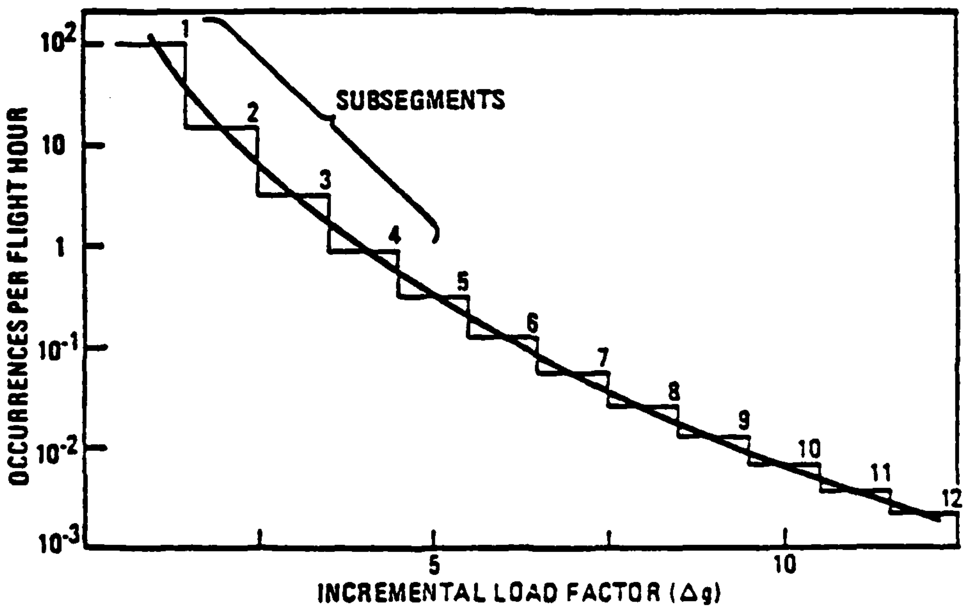


Figure 4-14. Typical Segment Load Frequency Curve

Solving for the derived gust velocity,

$$U_{de} = \frac{\Delta g}{m S V_e K_g \rho_o / (2W)}$$

U_{de} is then calculated for each subsegment, and the curves of Figure C13-37 of Reference 5 are used to find the frequency of occurrence.

For maneuver loads, Figure C13-41 of Reference 5 shows incremental load factor versus frequency of occurrence. For taxi loads, Figure C13-46 of Reference 5 shows incremental load factor versus frequency of occurrence. Incremental load factor versus frequency of occurrence for landing loads was averaged from data for two commercial transport aircraft.

The resulting fatigue load spectrum is shown in Table 4-13. The number of cycles is based 10,000 flights. The variation between cycles and flights is linear, so that linear ratioing of cycles and design life is valid.

Table 4-12. Typical Transport Flight Profile

	Segment Description	Gross Weight (kips)	Altitude (ft x 10³)	KEAS*	Mach No.	Distance Statute Miles)
	1 Taxi; takeoff run, ldg. roll	358.3	S.L.			
Maneuver Segments	2 Climb (Flaps down 25°)	352.2	0 - 5	223	.355	8.15
	3		5 - 10	250	.435	12.51
	4		10 - 20	340	.634	47.53
	5 Climb	352.2	20 - 35	319	.836	150.70
	6 Cruise	341.4	35	273	.85	395.58
	7 Descent	335.4	35 - 20	319	.836	53.29
	8		20 - 10	340	.684	33.33
	9 (Flaps down 15°)		10 - 5	250	.435	23.45
	10 Descent (Flaps down 50°)	335.4	5 - 0	223	.355	14.11
Gust Segments	11 Climb (Flaps down 25°)	352.2	0 - 5	223	.353	8.15
	12		5 - 10	250	.435	12.51
	13		10 - 20	340	.634	47.53
	14 Climb	352.2	20 - 35	319	.836	150.70
	15 Cruise	341.4	35	273	.85	395.58
	16 Descent	335.4	35 - 20	319	.836	53.29
	17		20 - 10	340	.684	33.33
	18 (Flaps down 15°)		10 - 5	250	.433	23.45
	19 Descent (Flaps down 50°)	335.4	5 - 0	223	.355	14.11
	20 Landing	334.7	S.L.	128		

*Knots equivalent airspeed

Table 4-13. Typical Transport Fatigue Spectrum — Cycles Per 10,000 Flights

SUBSEGMENT		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
SEGMENT NO.	LOAD TYPE*	Δg .10	Δg .15	Δg .20	Δg .25	Δg .30	Δg .35	Δg .40	Δg .45	Δg .50	Δg .60	Δg .70	Δg .80	Δg .90	Δg 1.00	Δg 1.10	Δg 1.20
1	2-2	2349957		249957		15070		882		43							
2	2-1	216970		10867		823		120		28	8	3	1	.4			
3	2-1	41700		5212		834		199		81	17	7	3	1	.6		
4	2-1					6990		2502		951	336	190	90	45	24	14	8
5	2-1	100167		13700		3014		685		198	60	24	11	6			
6	2-1	113023		8417		1236		263		78	25						
7	2-1	48146		5921		1211		296		85	28	11	5	2			
8	2-1					6060		2083		833	333	169	79	42	22	12	7
9	2-1			13794		2168		558		156	52	20	8	4	2	.9	
10	1-1	486552		22397		1987		282		61	18	7	3	1			
11	1-1	4320	1328	418	151	51	18	7	3	2							
12	1-1	6630	2039	688	231	78	28	11	5	2							
13	1-1	25191	7747	2614	879	295	106	42	19	9							
14	1-1	79871	24504	8288	2788	931	347	132	59	30							
15	1-1	209657	61480	21757	7318	2453	882	347	154	77							
16	1-1	28211	8686	2931	986	330	119	47	21	10							
17	1-1	17665	5433	[illegible]	617	207	74	29	13	6							
18	1-1	12128	3822	1290	434	145	52	21	9	5							
19	1-1	7178	2300	776	261	87	31	12	6	3							
20	3-2				508.	7030.	1500.			845.		104.		13.			

* 1-1 MANEUVER — 2-2 TAXI
3-2 LANDING IMPACT — 2-1 GUST

The flight profile used as the basis for developing a typical fighter service load spectrum is presented in Table 4-14 This profile presents the segments of an air-to-air combat mission for a typical lightweight fighter. Maneuver loads for the flight segments were obtained from Table I of reference 6, which presents the data in the form of load factor versus cumulative occurrences. In conjunction with the foregoing data, a representative supersonic air-to-air combat spectrum has been added as shown in Table 4-15. Taxi load factor versus cumulative occurrence data was obtained from Table VIII of reference 6. Incremental load factor versus frequency of occurrences for the landing segment was derived from the sink speed versus landing sink speed was converted to vehicle load factor by assuming a landing gear stroke of 12 inches and oleo efficiency factor of 0.8.

Table 4-14

TYPICAL LIGHTWEIGHT FIGHTER AIR-TO-AIR COMBAT MISSION

Segment	Gross Weight (lb)	Altitude (1,000 ft)	Mach No.	Distance (n mi)	Time (min)
1. Taxi	12,855	SL	-	-	-
2. Climb	12,855 - 12,480	0 - 46	0.72 - 0.85	42.6	5.364
3. Cruise	12,480 - 12,175	46	0.85	112.3	13.820
4. Combat	12,175 - 12,005	30	0.90	-	0.620
5. Accelerate	12,005 - 11,740	30	0.9 - 1.4	8.15	0.707
6. Combat	11,740 - 10,260	30	1.4	-	1.125
7. Cruise	10,260 - 9,920	50	0.85	154.9	19.290
8. Loiter	9,920 - 9,625	10	0.33	-	15.0
9. Landing	9,625	SL	-	-	-

Table 4-15

CUMULATIVE OCCURRENCES PER 1,000 FLIGHT HOURS
OF SUPERSONIC AIR-TO-AIR COMBAT

Load Factor N_Z	Cumulative Occurrences
10.0	0
9.0	0
8.0	16
7.0	90
6.0	500
5.0	2,900
4.0	17,000
3.0	90,000
2.0	250,000
1.5	320,000
0.0	16,000
-1.0	45
-2.0	0.1
-3.0	0
-4.0	0

TABLE 4-16 TYPICAL AIR-TO-AIR FIGHTER FATIGUE SPECTRUM - CYCLES PER 1,000 FLIGHTS

Subsegment		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Seg. No.	Load type	Δg 1.5	Δg -1.0	Δg -.50	Δg .25	Δg .05	Δg .10	Δg .15	Δg .20	Δg .25	Δg .30	Δg .35	Δg .50	Δg 1.0	Δg 1.5	Δg 2.0	Δg 2.5	Δg 3.0	Δg 3.5	Δg 4.0	Δg 4.5
1	2-2					229,000	135,000	78,500	35,000	12,300	3,150	840	210								
2	1-1												1,857.7	63.5							
3	1-1												2,556.7	985.8	230.3	4.6					
4	1-1	0.6	11.8	442.3									1,705	1,384.7	682	191.2	50.2	12.2	3.6	0.9	0.2
5	1-1												130.8	50.4	11.8	0.2					
6	1-1		0.1	5.6	294.3								2,462.5	2,306.3	603.8	105	18.6	3.2	0.7		
7	1-1												3,568.7	1,376	321.5	6.4					
8	1-1												6,300	1,265	165.5	18.3	1.3				
9	3-2					325	180	107	61	32	18	17.2	9	0.9							

Net limit loads due to the air loads, inertia loads, and landing gear loads for various flight and ground conditions are input to the program.

The loading conditions are separated into two groups. The first group consists of from one to six conditions. These conditions are specified by the user and are used to size the structure so as to preclude static strength failures and to meet residual strength requirements. The second group consists of the six conditions listed in Table 4-17. These conditions are used to define the fatigue stress spectrum described used in the structural analysis.

Table 4-17. Fatigue Spectrum Loading Conditions.

Condition Number	Description
1	1G Taxi
2	1G Level Flight
3	2G Vertical Gust
4	2G Maneuver
5	1G Landing Impact
6	Maximum Pressure (Fuselage)

Each loading condition defines the six components of load (AX, XS, ZS, TOR, XM, ZM) at up to 20 stations along the structure. The sign convention used is presented in Figure 4-15. A typical fuselage loading condition is illustrated in Figure 4-16 Steps in the loading curves are represented by repeating stations with the two different load component values. The reference axis used for input loads is the centerline for fuselages and line midway between the front and rear spars for aerodynamic surfaces.

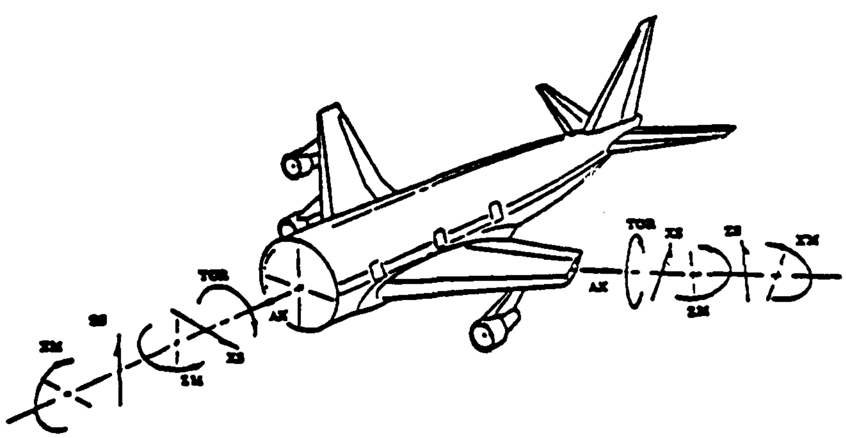


Figure 4-15 External Loads Sign Convention

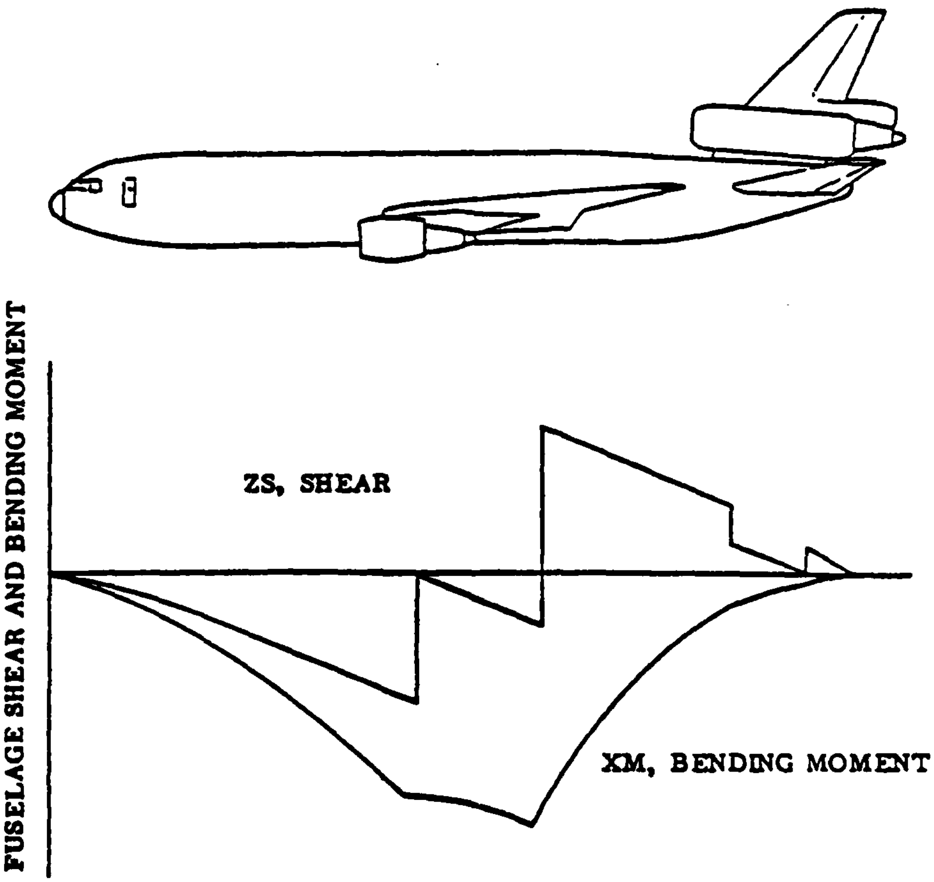


Figure 4-16. Typical Fuselage Load Condition

STRUCTURAL DESIGN PROCEDURE

The structural design procedure starts with the input design, then through a series of design analysis and redesign iterations produces a final design,which satisfies the design criteria. The iteration process continues until two successive iterations produce a change in weight that is within a specified tolerance.

The design analysis involves the comparison of applied stresses and allowable stresses. The internal load solution is used to calculate the applied stresses. The box beam ine internal load solution was selected instead of a finite element solution in order to keep computer execution time at an acceptable level. This selection restricts this procedure to relatively clean beam-like structures. However, decoupling of internal loads from one station to the next is basic to the box beam theory. Hence the overall design problem is reduced to a series of cross-section design problems at discrete locations along the structure.

The procedure used to design the cross-section is a two-part procedure. The first part, the section sizing procedure, adds or subtracts material from the structural elements of the cross-section in order to produce a zero margin or minimum gage design. The second part employs a non-linear programing technique to maximize the efficiency of each element while maintaining a constant weight design. This element optimization procedure is then iterated with the section sizing procedure until the design converges. Convergence occurs when two successive iterations produce a change in weight that is within a specified tolerance.

SECTION SIZING PROCEDURE. The section sizing procedure sizes the structure based on design criteria such as static strength, stability, service life, and residual strength.

The procedure used to size the structure is:

a. Analyze the structure as it is defined by the input data.

b. Predict new skin thickness and stiffener area based on the analysis results.

c. Re-analyze the structure as predicted in b.

Steps b. and c. are iterated until the minimum weight structure satisfying the design criteria is found. During this process, material is added or removed from the panel such that the design proportions produced in the optimization phase are maintained.

The equivalent thickness ($\bar{t}$) of a structural panel is computed:

$$\bar{t} = t_{sk} + \frac{\rho_{st}}{\rho_{sk}} \cdot \frac{A_{st}}{B_{st}}$$

where: t_{sk} - skin thickness [in.]

A_{st} - stiffener area [in.^{2}]

B_{st} - stiffener spacing [in.]

ρ_{st} - stiffener material density [lb./in.^{3}]

ρ_{sk} - skin material density [lb./in.^{3}]

The technique employed in step b. to predict the new $\bar{t}$ is described below. The new $\bar{t}$ is predicted by passing a parabola through three points on a plot of $\bar{t}$ versus margin of safety, MS. The points are (TBAR = 0, MS = -1), ($\bar{t}_i$, MS t_i), ($\bar{t}_{i+1}$, MS ($\bar{t}_{i+1}$), see Figure 4-17 The new $\bar{t}$ is found by solving for the proper root of the resulting equation. The process is started by assuming the slope at $\bar{t} = 0$ to be 0 for the first iteration.

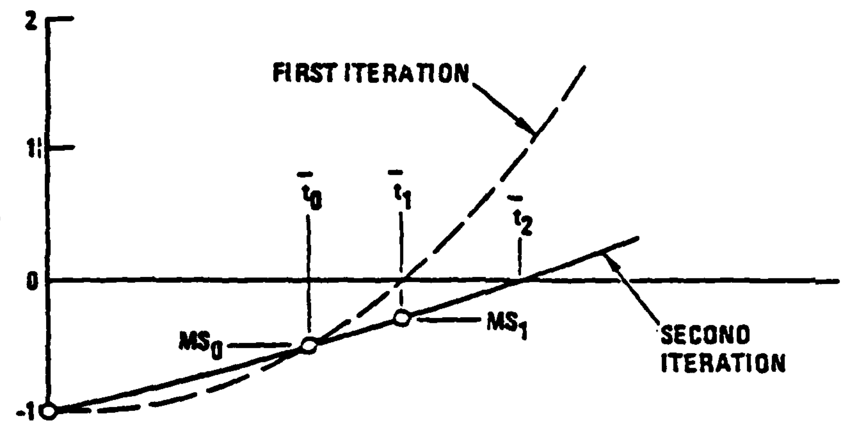


Figure 4-17 Resizing Procedure

ELEMENT OPTIMIZATION PROCEDURE. The element optimization procedure is used to adjust detail dimensions of an element so as to make the most efficient use of the material while maintaining a given weight. For example, refer to Figure 4-18. The panel element shown contains eight detail dimensions or design variables. All of the design variables or as few as one may be active, depending on the choice of the user. The inactive design variables are treated as constants and remain unchanged. The object of the optimization procedure is to find the optimum set of active design variables, i.e., the set that describes the most efficient panel of a given weight within the boundaries imposed by upper and lower limits on the detail dimensions. For example, suppose that all of the design variables are active for the panel shown in Figure 4-18. The panel weight is given by:

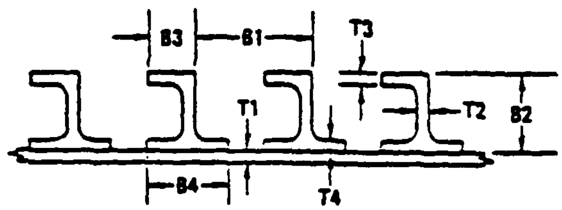


Figure 4-18. Typical Panel Construction

$$W_p = (\rho_{sk} \cdot T1 + \rho_{st} \cdot A_{st}/B1) * \text{Panel Area}$$

where,

$$A_{st} = T2 \cdot B2 + T3 \cdot B3 + T4 \cdot B4 \quad [\text{in.}^2]$$

$$\text{Panel Area} = \text{Panel Length} \cdot \text{Panel Width}$$

Since the panel area is not changing, the panel weight is constant if the unit weight w_p is constant:

$$w_p = W_p \,/\, \text{Panel Area}$$

$$w_p = \rho_{sk} \cdot T1 + \rho_{st} \, (T2 \cdot B2 + T3 \cdot B3 + T4 \cdot B4)/B1$$

Given any seven design variables, the density of the skin, ρ_{sk}, and the stiffener, ρ_{st}, and a unit weight w_p, the eighth design variable can be found from

$$T1 = [w_p - \rho_{st} \, (T2 \cdot B2 + T3 \cdot B3 + T4 \cdot B4)/B1]/\rho_{sk}$$

For this example, there are seven independent active design variables and one dependent active design variable, T1. A non-linear math programming routine is employed to find the optimum set of independent active design variables. The most efficient design is defined by that set of active design variables for which the following function is minimum.

$$P = \frac{1}{L \cdot J} \sum_{l=1}^{L} \sum_{j=1}^{J} F\,(MS_{l,j}) + F\,(MC)$$

where: l denotes the failure mode

j denotes the loading condition

MS = margin of safety

MC = side constraint margin for the dependent active design variable, $(T1-T1_{min})/T1_{min}$

The function F is given by:

$$F(x) = 1/x \qquad x \geq \epsilon$$

$$F(x) = [x/\epsilon \; (x/\epsilon - 3) + 3]/\epsilon \qquad x < \epsilon$$

where $\epsilon = 0.01$.

The independent active design variables are kept within upper and lower boundaries by means of a mapping function. These detail dimension variables are transformed into optimization variables, and back into detail dimension variables by the mapping function presented in Figure 4-19. This mapping technique provides for bounded design variables without imposing constraints on the optimization variables.

The optimization problem posed in the following manner is an unconstrained non-linear mathematical programing problem. A number of techniques are available to solve this

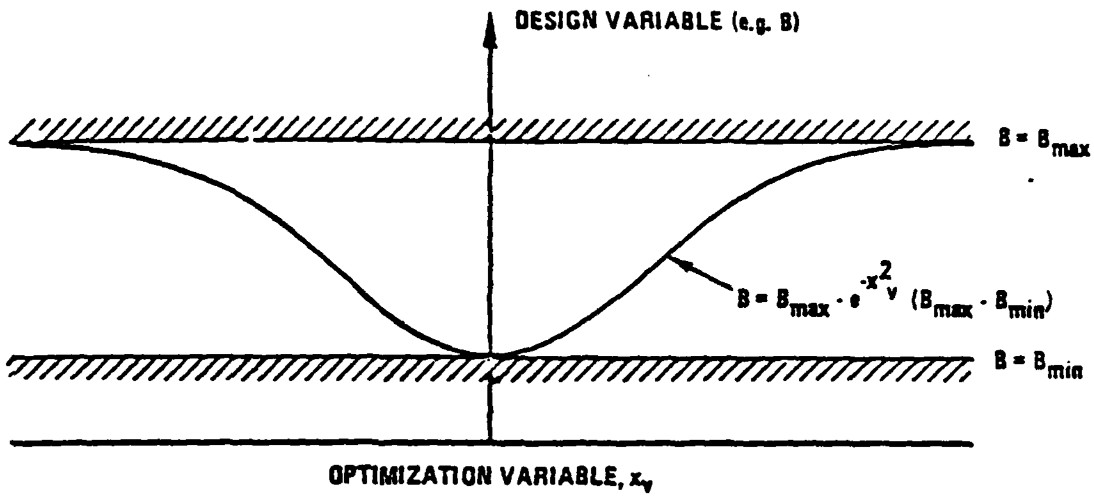


Figure 4-19. Design Variable Mapping Function

problem; the method used by APAS III is the Fletcher-Powell-Davidon unconstrained minimization technique (Reference 7).

STRUCTURAL ELEMENT SYMMETRY GROUPS

A symmetry group is a group of structural elements that have identical designs. When a number of structural elements are placed into the same symmetry group, only one design is produced. The design of the element respects all of the margins of safety for all of the elements in the group. This technique provides a means by which fuselage centerplane symmetry can be respected without duplicating reversible loading conditions. It is often desirable to make adjacent panel elements identical for ease in manufacturing. This can be accomplished with symmetry grouping also. Since the use of symmetry groups reduces the number of independent design variables of the structure, it can be significant in reducing execution time and should be employed wherever possible.

STRUCTURAL ANALYSIS

This section presents the techniques used to calculate the applied stresses, including the fatigue stress spectrum, and the methods used to calculate margins of safety for static strength, fatigue, flaw growth, and residual strength criteria.

INTERNAL LOADS ANALYSIS. The internal loads analysis is based on classical box beam theory (Reference 5). The assumptions made are: plane sections remain plane under the action of bending moments and axial loads, cross sections are free to warp when torque is applied, and the structure obeys a linear elastic stress-strain law.

Axial Stress. The axial stresses are made up of stresses due to axial loads, and stresses due to bending moments. The equation used to calculate the axial stresses is:

$$\sigma = E\epsilon$$

where: E - Modulus of elasticity [psi]

ϵ - Strain (computed as shown below) [in./in.]

$$\epsilon = \frac{M_x(EI_{xz}) - M_z(EI_{xx})}{(EI_{xx})(EI_{zz}) - (EI_{xz})^2}(x-\bar{x}) + \frac{M_z(EI_{xz}) - M_x(EI_{zz})}{(EI_{xx})(EI_{zz}) - (EI_{xz})^2}(z-\bar{z}) + \frac{P}{AE}$$

where: M_x = Net bending moment about a horizontal axis passing through the centroid [in.-lb.]

M_z = Net bending moment about a vertical axis passing through the centroid [in.-lb.]

P = Axial load [lb.]

x, z = Coordinates of the element, see Figure 4-20 [in.]

$\bar{x}, \bar{z}$ = Coordinates of the centroid, see Figure 4-20 [in.]

EI_{xz}, EI_{xx}, EI_{zz}, AE = Section properties, see next section.

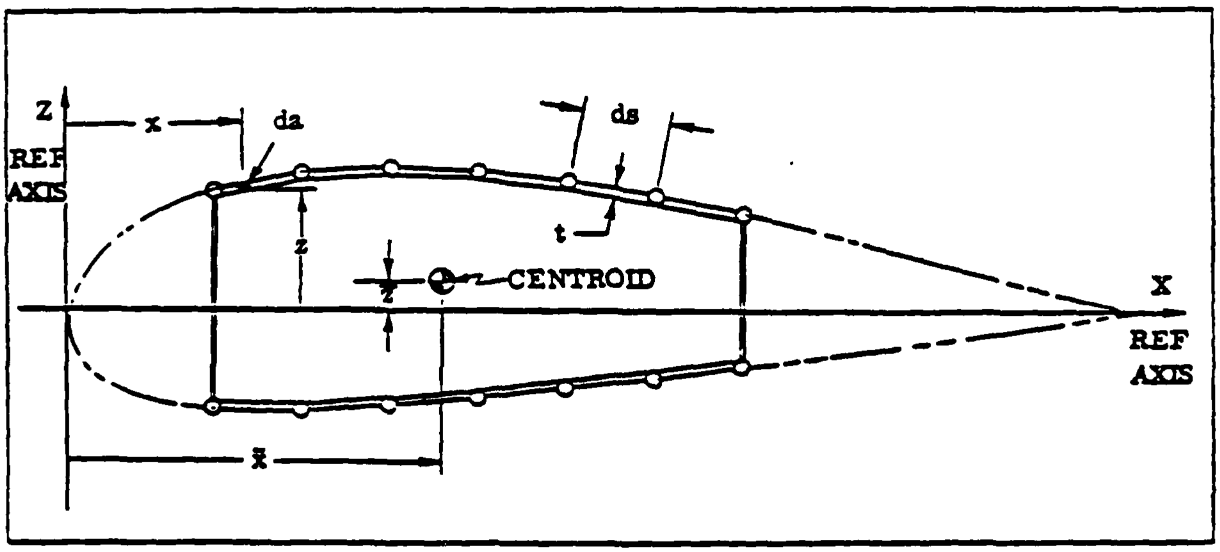


Figure 4-20 Typical Wing Section

Shear Stresses. The shear stresses resist the external shear forces and the torque applied to the section. Under the basic assumptions the shear flow is calculated using a VQ/I distribution for the shear forces. The resultant applied torsion is due to the applied torque, TOR, and the couples resulting from shifting the shear forces XS and ZS to the shear center. This net torsion is resisted internally by a shear flow distributed according to a T/2A distribution. In the case of multiple cell structures such as multi-spar wings, the cells are assumed to have equal twisting angles. For a further description of the method see Paragraphs 17.9 through 17.11 of Reference 8.

SECTION PROPERTIES. Section properties of the cross section of the wing or fuselage are calculated at each station where structural sizing is performed. These properties are used to calculate the internal loads distribution and to provide stiffness information. In order to simplify the calculation of section properties the following assumptions are made: (1) the material that resists bending moments is assumed to be smeared uniformly between nodal points, (2) only the skin and shear webs are effective for resisting shear loads and torsion. The following equations are used to calculate section properties (see Figure 4-20).

$$EA = \int E \, da$$

$$\bar{x} = \frac{1}{EA} \int E \, x da$$

$$\bar{z} = \frac{1}{EA} \int E \, z da$$

$$EI_{xx} = \int E \, z^2 \, da - EA \cdot \bar{z}^2$$

$$EI_{zz} = \int x^2 \, da E - EA \cdot \bar{x}^2$$

$$EI_{xz} = \int E \, xz da - EA \cdot \bar{x} \cdot \bar{z}$$

where: x, z are the coordinates of the incremental area da [in.]

EA is the axial stiffeness of the cross-section [lb.]

$\bar{x}, \bar{z}$ are the coordinates of the centroid of the cross-section [in.]

EI_{xx} is the moment of inertia of A taken about an x axis passing through the centroid multiplied by E [lb.-in.^{2}]

EI_{zz} is the moment of inertia of A taken about a z axis passing through the centroid multiplied by E [lb.-in.^{2}]

EI_{xz} is the product of inertia of A with respect to the centroid multiplied by E

STATIC STRENGTH ANALYSIS. The depth of the static strength analyses performed by APAS IV is consistent with typical pre-design stress analyses. The analytical techniques and their sources are described in this section. The failure modes included are summarized in Table 4-18. APAS IV computes margins of safety for each failure mode and uses these values to direct structural design optimization. The critical failure mode margin of safety is included in the computer output for each element and load condition.

Table 4-18. Panel Element Failure Modes

Failure Mode	Panel Construction Type (see Figure 2-4)											
	1	2	3	4	5	6	7	8	9	10	11	12
Local Buckling	•	•	•	•	•	•	•	•	•			
Diagonal Tension	•	•	•	•	•	•	•	•	•			
Crippling	•	•	•	•	•	•	•	•	•			
Inter-Rivet Buckling and Wrinkling				•	•	•	•	•	•			
Panel General Instability										•	•	•
Wide Column Buckling	•	•	•	•	•	•	•	•	•			
General Yielding	•	•	•	•	•	•	•	•	•	•	•	
Distortion Energy Theory	•	•	•	•	•	•	•	•	•	•	•	
Maximum Fiber Strain in a Laminate												•

Local Buckling (Compression and Shear)

Critical local buckling stresses for compression and shear loading are computed by APAS IV using the following equations. These equations were obtained from Reference 5.

Compression Buckling

$$F_{cr} = \frac{\pi^2 k_c E}{12(1 - \nu_e^2)} \left(\frac{t}{b}\right)^2$$

where: F_{cr} - critical compression buckling stress [psi]

k_c - compression buckling coefficient [dimensionless]

E - modulus of elasticity [psi]

ν_e - elastic Poisson's ratio [dimensionless]

t - thickness [in.]

b - short dimension of plate or loaded edge [in.]

Shear Buckling

$$F_{scr} = \frac{\pi^2 k_s E}{12\,(1 - \nu_e^2)} \left(\frac{t}{b}\right)^2$$

where: F_{scr} - critical shear buckling stress [psi]

k_s - shear buckling coefficient [dimensionless]

b - short dimension of plate [in.]

The buckling coefficient is dependent on the aspect ratio of panel length/width and panel edge fixity. For APAS IV, the aspect ratio is assumed to be large and the corresponding asympototic value of the buckling coefficient for the appropriate edge fixity is used. Typical values of shear and compression buckling coefficients for various edge fixity conditions are shown in Figure 4-21. The actual coefficients used in APAS IV for each available type of stiffened skin panel construction are shown in Figure 4-22.

For some flight vehicle designs, it may be a requirement that buckling of the skin panels is not permitted up to a specified percent of limit load. APAS IV has the capability to handle this design criterion. Both shear and compression buckling are considered. The interaction equation used in APAS IV to combine the effects of shear and compression was taken from Reference 5 and is presented below:

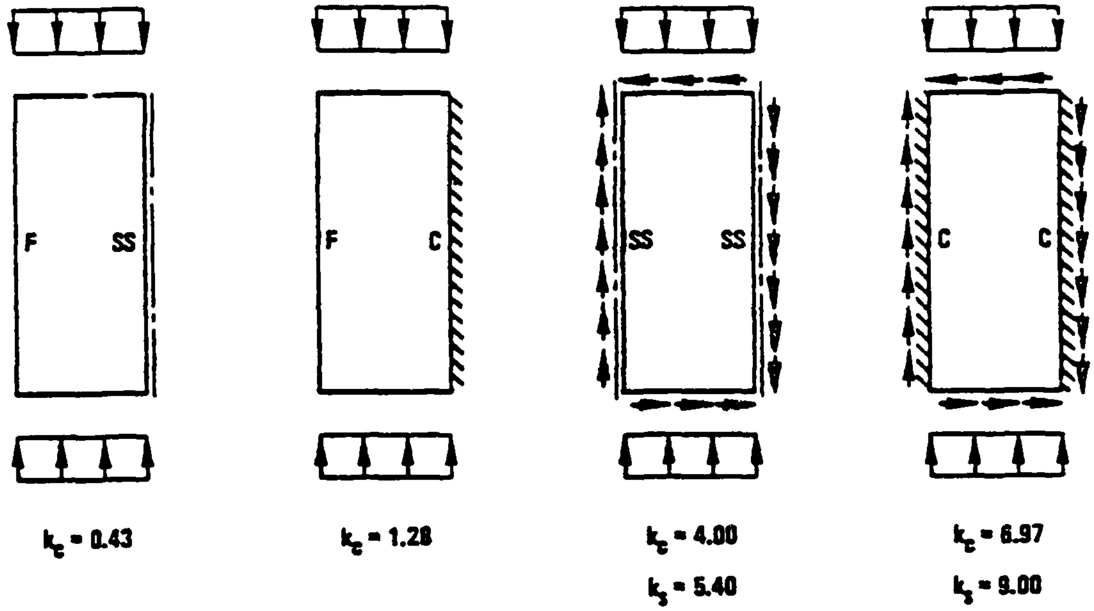
$$R_c + R_s^2 = 1.0$$

where: R_c - applied compression stress/compression buckling stress

R_s - applied shear stress/shear buckling stress

The associated margin of safety equation is:

$$M.S. = \frac{2}{R_c + \sqrt{R_c^2 + 4\,R_s^2}} - 1$$



LEGEND: F – FREE EDGE
SS – SIMPLY SUPPORTED EDGE
C – CLAMPED

Figure 4-21. Shear (k_s) and Compression (k_c) Buckling Coefficients for Various Edge Fixities

Diagonal Tension Analysis

Maximum allowable panel shear stresses are determined by APAS IV using the relationship shown in Figure 4-23. Parameters F_s and F_{su} are the maximum allowable shear and the material ultimate shear, respectively. Parameter F_{scr} is critical shear stress at which shear buckling initiates. The equation used by APAS IV to compute F_{scr} is described in the local buckling failure mode section.

Crippling

The method for the crippling analysis used in APAS IV was taken from Reference 9. The crippling strain for the combination of stiffener and effective skin is computed by the following equation:

$$\epsilon_{cc} = \left[\frac{\Sigma b_n t_n f_{ccn}}{\Sigma b_n t_n E_n} \right]$$

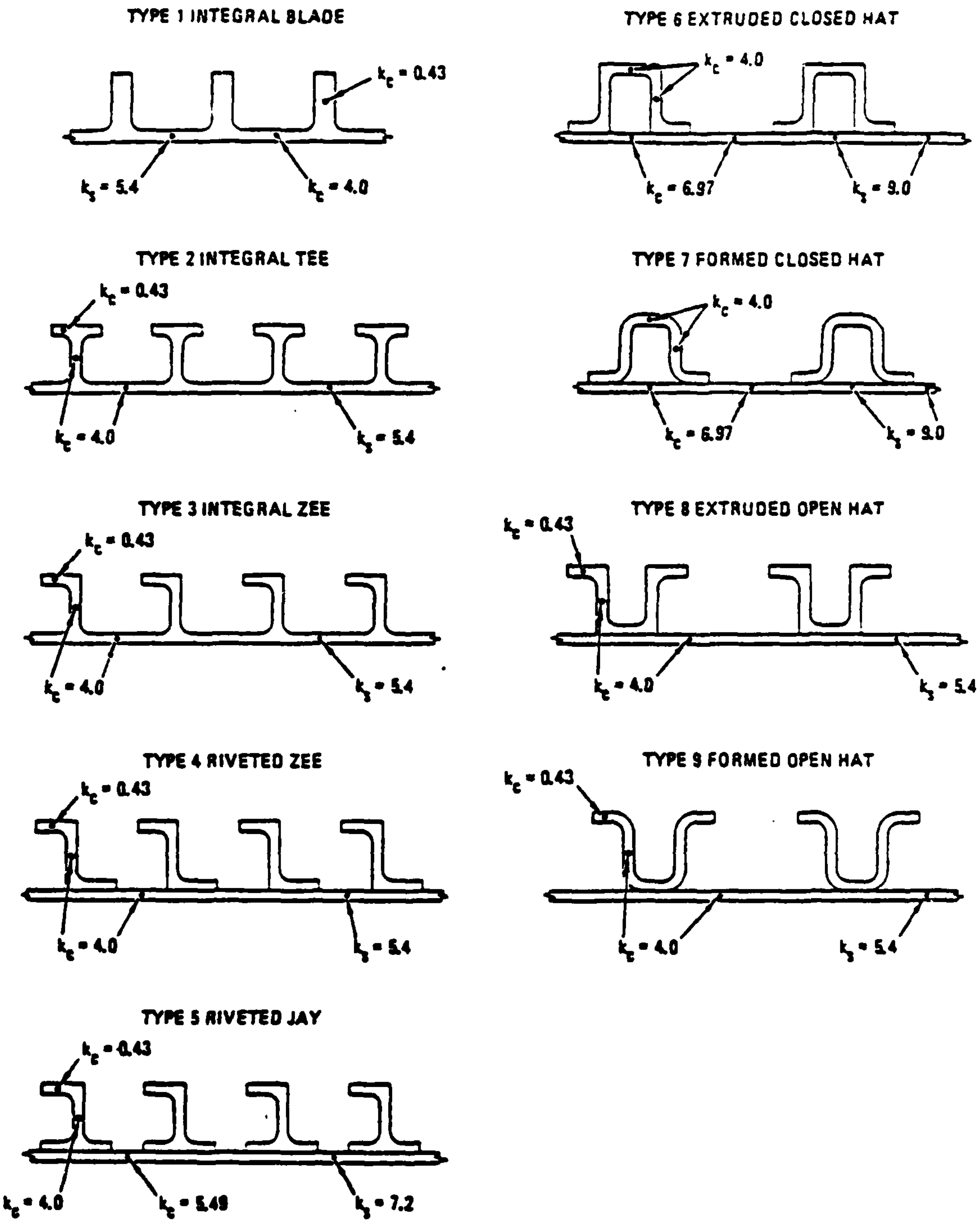


Figure 4-22. Compression and Shear Bucklin₆ Coefficients for Each Skin Panel Construction Type

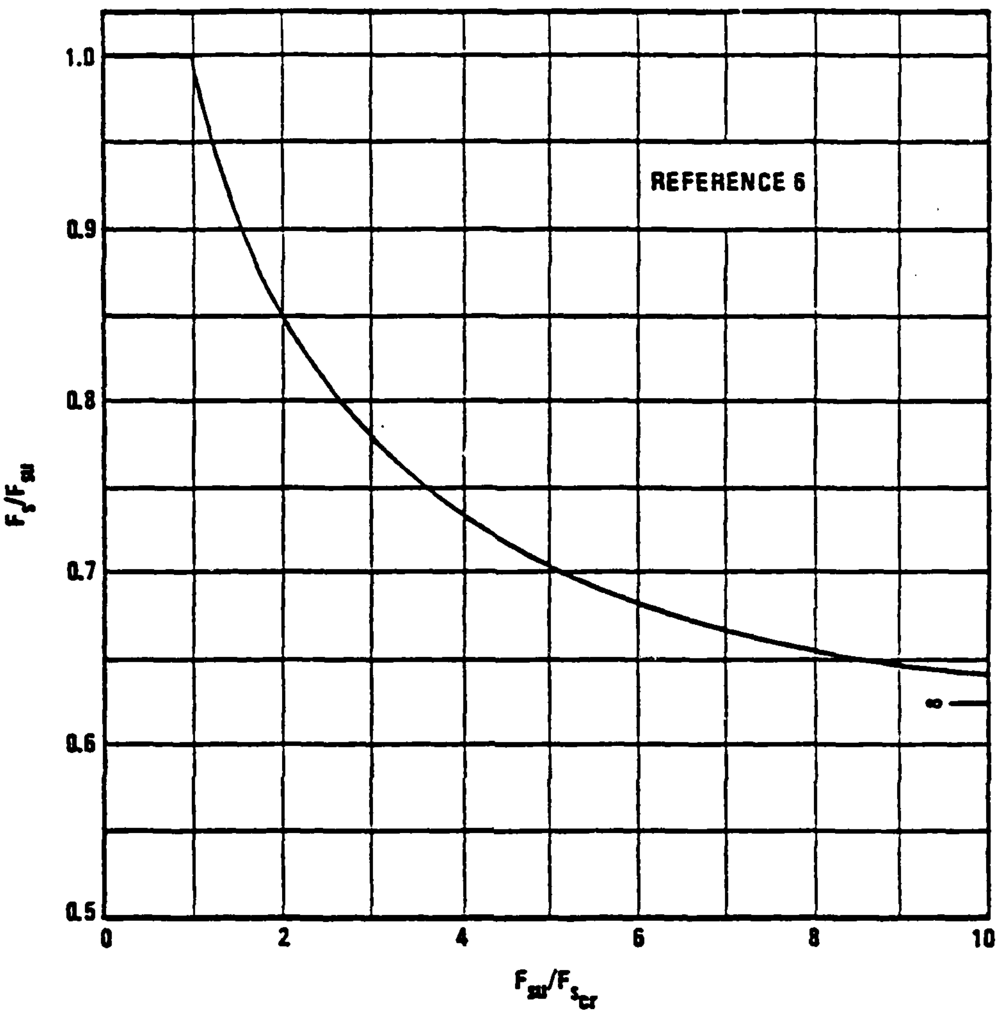


Figure 4-23. Diagonal Tension Chart

where: ϵ_{cc} - crippling strain for section [in./in.]

E_n - modulus of elasticity of element n [psi.]

b_n - effective element width [in.]

t_n - element thickness [in.]

f_{ccn} - element crippling stress [psi.]

The element crippling stress (f_{ccn}) is obtained from Figure 4-24.

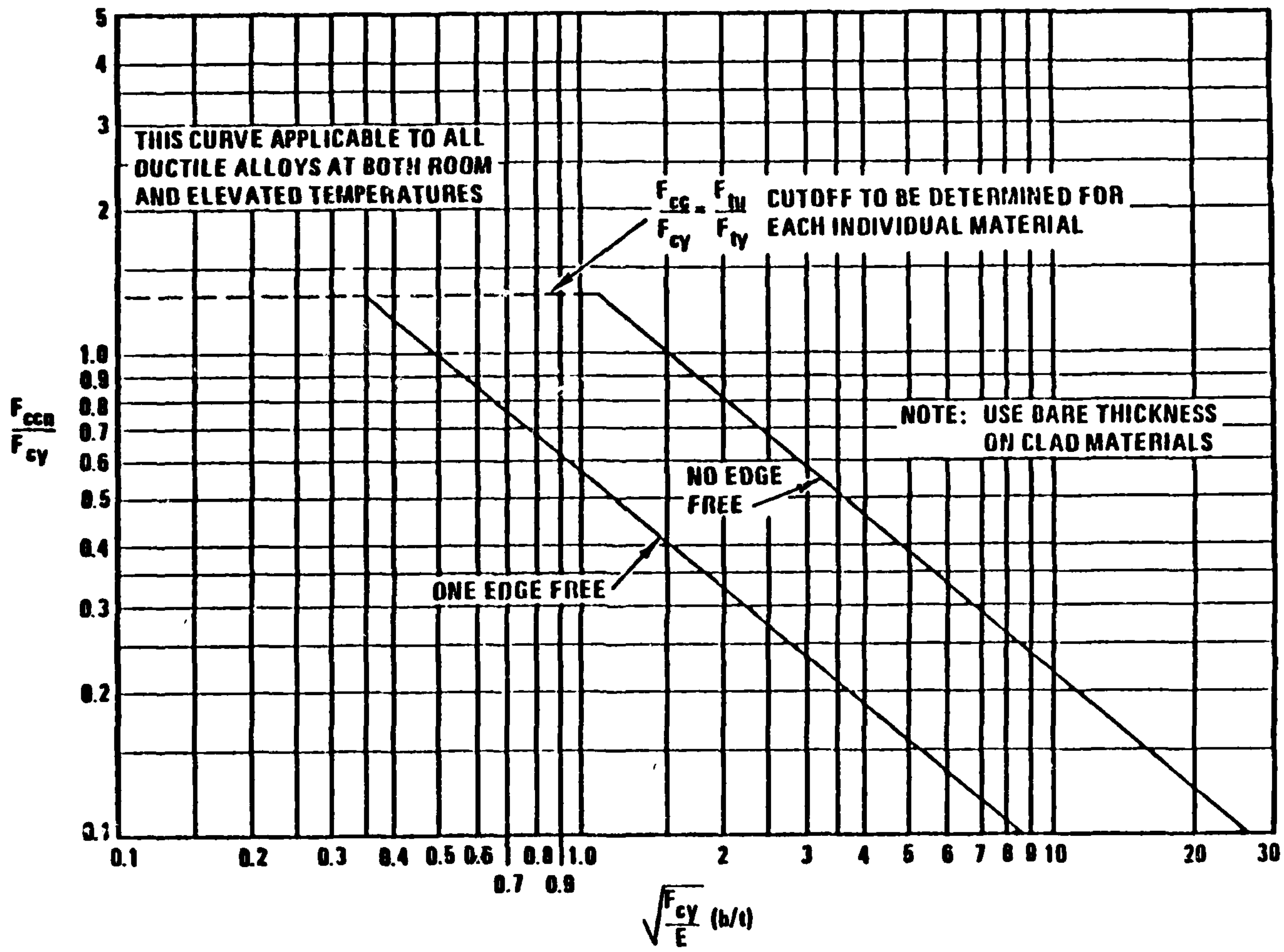


Figure 4-24. Nondimensional Crippling Curves

Inter-Rivet Buckling and Sheet Wrinkling

Inter-rivet buckling involves a failure of the skin between rivets. When both the skin and the stiffener fail, it is known as a wrinkling failure. APAS IV checks for both of these failure modes using the methods taken from Reference 5. Inter-rivet buckling strain is computed using the following equation:

$$\epsilon_{ir} = \frac{C\,\pi^2}{12\,(1 - \nu_e^{\,2})} \left(\frac{t_s}{P}\right)^2$$

where: ϵ_{ir} - inter-rivet buckling strain [in./in.]

C - end fixity (C equals 4, for all cases) [dimensionless]

t_s - skin thickness [in.]

P - rivet pitch [in.]

E - modulus of elasticity [psi]

ν_e - Poisson's ratio [dimensionless]

Rivet pitch spacing is set equal to four times the rivet diameter for all cases. The rivet diameter for each case is selected based on skin thickness according to Table 4-19.

Table 4-19. Rivet Diameter Versus Skin Thickness
cm, (inches)

Skin Thickness (t_s)	
0.000	(0.000)
0.064	(0.025)
0.127	(0.050)
0.318	(0.125)
0.635	(0.250)

Rivet Diameter	
0.318	(0.1250)
0.397	(0.1563)
0.476	(0.1875)
0.635	(0.2500)

Sheet wrinkling strain is computed using the equation presented below:

$$\epsilon_w = \frac{k_w\,\pi^2}{12\,(1 - \nu_e^{\,2})} \left(\frac{t_s}{b_s}\right)^2$$

where: ϵ_w - wrinkling strain [in./in.]

k_w - wrinkling coefficient [dimensionless]

t_s - skin thickness [in.]

b_s - stringer spacing [in.]

The empirical wrinkling coefficient (k_w) is a function of the effective rivet offset and local geometry. The effective rivet offset is determined using Figure 4-25 and is used in Figure 4-26 to evaluate the wrinkling coefficient.

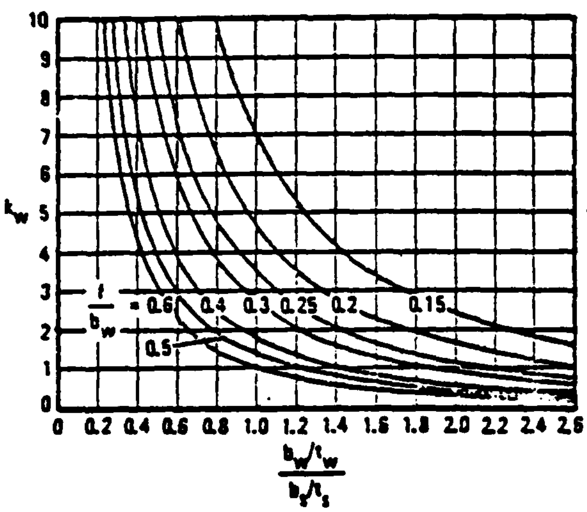


Figure 4-25. Experimentally Determined Values of Effective Rivet Offset

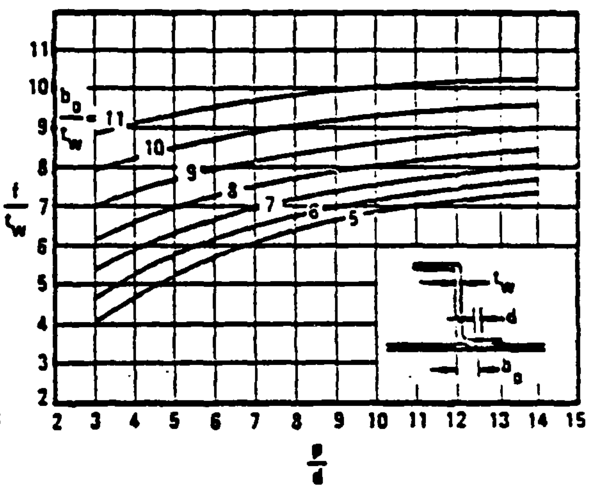


Figure 4-26. Experimentally Determined Coefficients for Failure in Wrinkling Mode

Panel General Instability

This section is a description of the analysis used to calculate general instability allowables for panel types 10, 11, and 12 (see Figure 4-8. This analysis procedure was taken from Reference 10. Design formulas are used to provide conservative estimates of the buckling allowables.

The moments of inertia and stiffnesses in both directions are calculated for a plate or sandwich panel in the conventional manner. See Figure 4-27 for sign convention used in the development of the design equations for buckling.

$$D_{11} = E_x I_y/(1 - \nu_{xy} \nu_{yx})$$

$$D_{22} = E_y I_y/(1 - \nu_{xy} \nu_{yx})$$

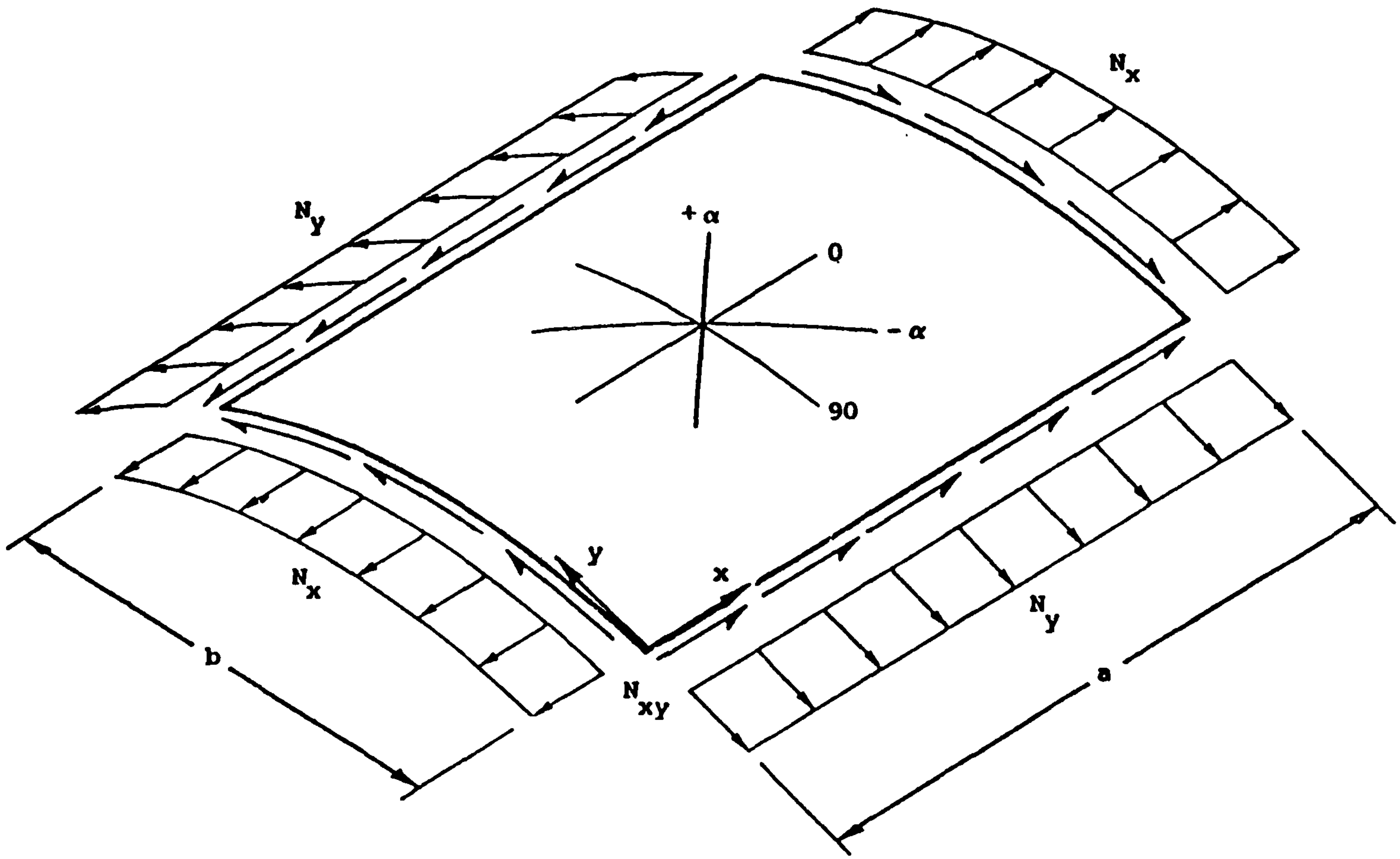


Figure 4-27. Panel Configuration

$$D_{12} = D_{11}\, \upsilon_{yx}$$

$$D_{66} = G_{xy}\, I_x$$

The shear buckling of a simply supported orthotropic plate can be reasonably estimated with the following formula

$$N_{xy_{cr}} = C_3 \quad \sqrt[4]{D_{11}\, D_{22}^3} \;/\; b^2$$

where: $C_1 = (b/a) \quad \sqrt[4]{D_{11}/D_{22}}$

$$C_2 = (D_{12} + 2D_{66}) \,/ \sqrt{D_{11}\, D_{22}}$$

$$C_3 = 32.8 + 20\, C_2 + 14.2\, (C_1)^{2.4} + 24.8\, C_2\, C_1^2$$

No simple correction for the effect of curvature on the shear buckling allowable is available at present.

The buckling allowable for a flat, simply-supported, orthotropic plate under biaxial loads may be found using the following method. Given a ratio

$$\alpha = N_x/N_y$$

the allowable in the axial direction may be expressed by

$$(N_{x_{cr}})_{panel} = \frac{\pi^2 \left[D_{11}\,(m/a)^2 + 2\,(D_{12} + 2D_{66})(n/b)^2 + D_{22}\,(n/b)^4 (a/m)^2 \right]}{1 + \alpha\,(an)^2 \;/\; (bm)^2}$$

where m and n are possible half-wave numbers into which the panel may buckle in the x and y directions, respectively. This formula is evaluated for the first five modes in each direction, and the minimum value is chosen. The allowable $N_{y_{cr}}$ is obtained similarly.

An estimate for the correction due to curvature on the compressive buckling allowable is obtained as described in Reference 8. The buckling allowable of the full cylinder from which the panel was cut is added to the flat plate allowable as obtained above. For an orthotropic cylinder, the cylinder buckling allowable is approximated as

$$(N_{x_{cr}})_{cylinder} = \frac{1}{2} \sqrt{E_x E_y}\;\; t^2 \,/\, [R \sqrt{3\,(1 - \upsilon_{xy}\, \upsilon_{yx})}\,]$$

where t and R are the thickness and radius of the cylinder, respectively.

The ratios of the applied loads to the allowables are formed:

$$R_s = N_{xy} / N_{xy_{cr}}$$

$$R_x = N_x / \left[(N_{x_{cr}})_{panel} + (N_{x_{cr}})_{cylinder} \right]$$

$$R_y = N_y / N_{y_{cr}}$$

The buckling margin of safety for each panel is calculated from the interaction equation

$$M.S. = \left[\frac{2}{R_x + R_y + \sqrt{(R_x + R_y)^2 + 4 R_s^2}} \right] - 1$$

The above analysis is brief and offers various degrees of approximation, depending on the complexity of the section being analyzed. For construction with orthotropic flat panels, it provides excellent estimates for the buckling allowables of simply supported panels. With the addition of curvature, it provides somewhat less accurate allowables.

Wide Column Buckling

This section is a description of the analysis used to calculate the general instability allowables for panel types 1 through 9, (see Figure 4-8).

Wide column buckling analysis of multi-rib structures assumes that the cover panel behaves as a simply supported column. The ribs, oriented perpendicular to the load, are assumed to provide the continuous simple supports. The effect of spar support at the unloaded edges of the column is ignored in this analysis. The method used by APAS IV for wide column analysis was taken from Reference 5 and is described below.

The relationship between critical column strain versus slenderness ratio (L'/ρ) is shown in Figure 4-28.

For large values of slenderness ratio, a form of the Euler column equation applies:

$$\epsilon_c = \frac{\pi^2}{(L'/\rho)^2}$$

where: ϵ_c - column failing strain [in./in.]

(L'/ρ) - slenderness ratio (effective length/radius of gyration)

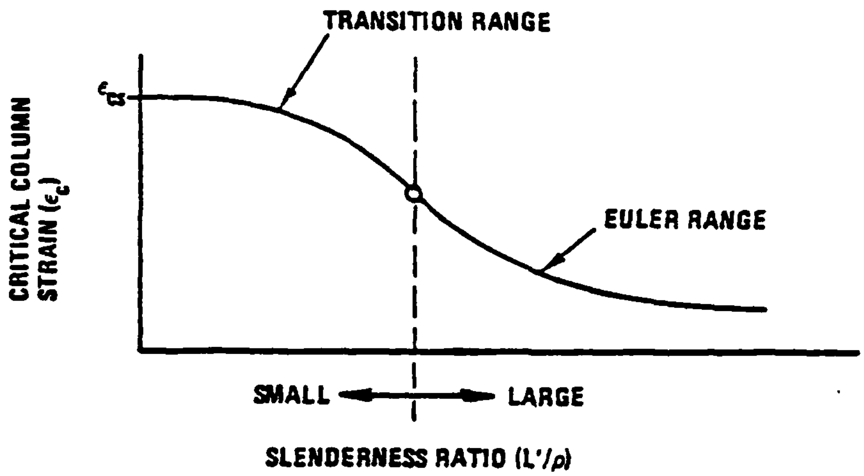


Figure 4-28. Critical Column Strain Versus Slenderness Ratio (L'/ρ)

For small values of slenderness ratio, the critical column strain transitions from the crippling strain to the Euler critical column strain. The following parabolic approximation is used to represent this transition.

$$\epsilon_c = \epsilon_{cs}\left[1 - \left(1 - \frac{\epsilon_{cr}}{\epsilon_{cs}}\right)\left(\frac{\epsilon_{cr}}{\epsilon_E}\right)\right]$$

where: ϵ_c - column critical strain [in./in.]

ϵ_{cs} - crippling strain [in./in.]

ϵ_{cr} - buckling strain for column cross-section [in./in.]

ϵ_E - Euler column strain [in./in.]

The equation applies for $\epsilon_c > \epsilon_{cr}$. Yield strain ($\epsilon_y$) is substituted for ϵ_{cr}, when $\epsilon_{cr} > \epsilon_y$.

General Yielding

To ensure that elastic stress conditions exist up to limit load for each structural design, APAS IV compares element tensile or compressive stresses to material yield for all loading conditions.

Distortion Energy Theory

The distortion energy theory (Hencky - Von Mises theory, Reference 11) is another failure mode criterion used by APAS IV. This theory is based on the assumption

that failure occurs when the distortion energy corresponding to the principal stress components equals the distortion energy at failure for the maximum allowable axial stress. This failure criterion is defined by the equation:

$$\sigma_1^2 - \sigma_1 \sigma_2 + \sigma_2^2 = \sigma_{max}^2$$

The boundary curve defined by this equation for all possible combinations of principal stresses is shown in Figure 4-29. Any principal stress combination that falls outside this boundary curve represents a negative margin of safety.

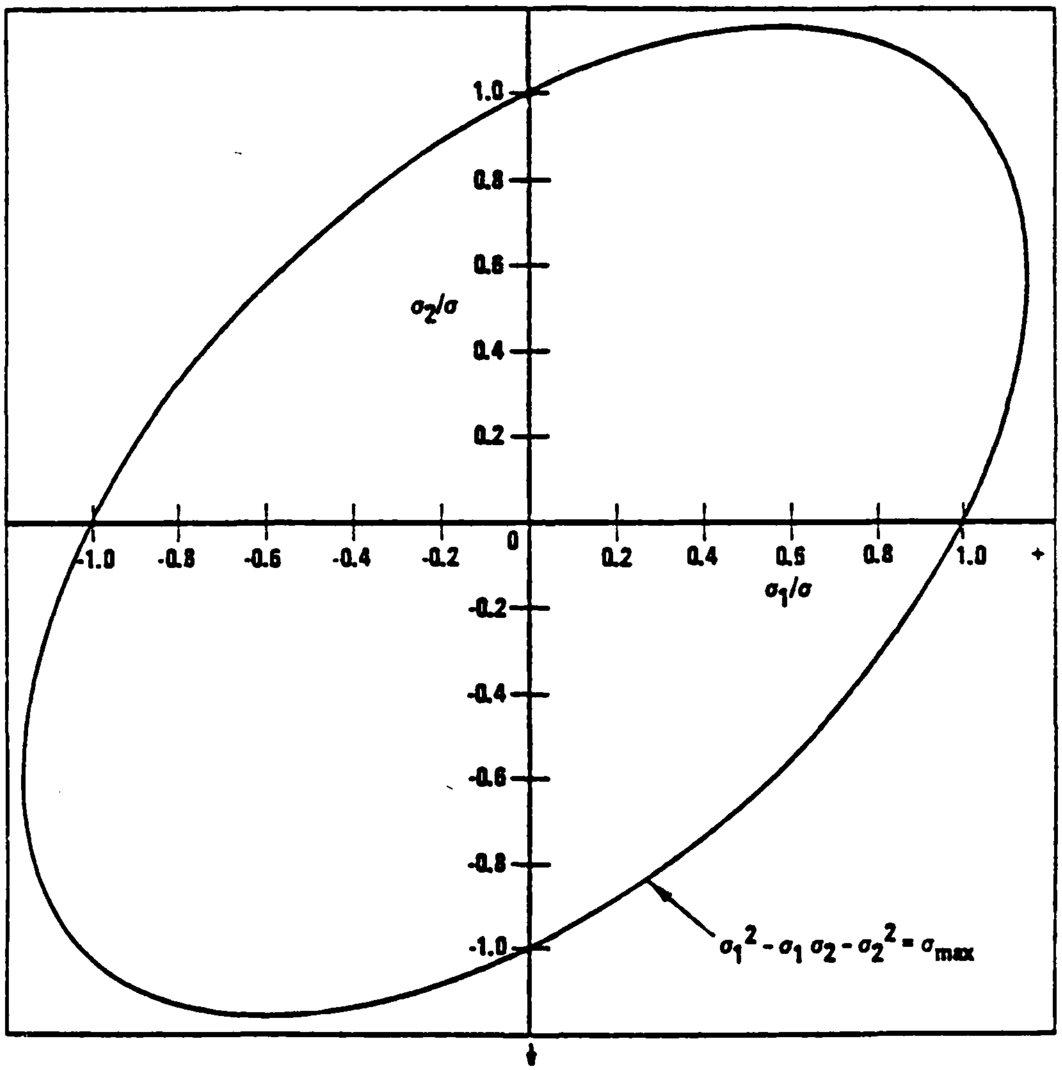


Figure 4-29 Distortion Energy Theory

Laminate Analysis

The composite panels (construction type 12) are specially orthotropic; if the panel is of sandwich construction, it is assumed that the core supplies no in-plane stiffness but is perfectly rigid in the out of plane direction, and that each of the composite faces carries one-half of the applied in-plane loads.

The laminate analysis is designed to find the strains in the 0°, 90°, and ± α° plies. The laminate longitudinal, transverse and shear strains, ϵ_x, ϵ_y, and ϵ_{xy} respectively, are calculated using the laminate in-plane constitutive matrix, [A], and the applied running loads, N_x, N_y, and N_{xy}, as shown in Figure 4-27.

$$\begin{Bmatrix} \epsilon_x \\ \epsilon_y \\ \epsilon_{xy} \end{Bmatrix} = [A^{-1}] \begin{Bmatrix} N_x \\ N_y \\ N_{xy} \end{Bmatrix}$$

The laminate strains are rotated using the transformation matrix, [T], for each ply angle in the laminate. These strains are used for computing the margins of safety.

The margins of safety for failure of a laminate of orthotropic materials are computed by using the six allowable failure strains of the basic lamina material and the orientation angle of each ply in the laminate. The strains are:

$+\epsilon_{11}$, tension in the 11 direction

$+\epsilon_{22}$, tension in the 22 direction

$+\epsilon_{12}$, positive shear

$-\epsilon_{11}$, compression in the 11 direction

$-\epsilon_{22}$, compression in the 22 direction

$-\epsilon_{12}$, negative shear

The laminate strains are calculated and then transformed to coincide with each ply material axis system as shown in Figure 4-30. The transformed strains are then compared with the appropriate allowable strains and three margins of safety are obtained for each ply, for each loading condition.

The minimum margin from all of the plies then becomes the final margin for the ultimate strain failure mode of the laminate. The equation used for each margin of safety is:

$$M.S. = \frac{\epsilon \, PSAL}{\epsilon} - 1$$

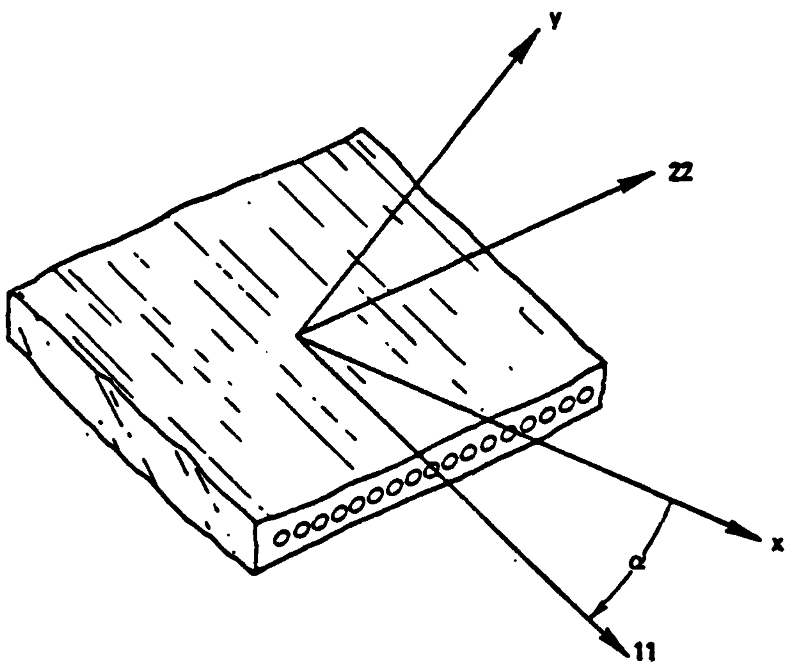


Figure 4-30. Coordinate Transformation for the α Ply

where $\epsilon PSAL$ is the ultimate strain allowable and ϵ is the applied strain.

FATIGUE STRESS SPECTRUM. The fatigue stress spectrum is based on the flight profile and load spectrum discussed in previous sections. It is made up of a group of minimum and maximum stresses and the number of applications expected during the design life. This spectrum is used for the fatigue analysis and the flaw growth analysis of the element discussed in this section.

Minimum and maximum stresses are calculated for each subsegment of the fatigue spectrum (see Table 4-13). These stresses are calculated from the segment constant stress σ_c and the segment alternating stress σ_a.

$$\sigma_{min} = \sigma_c - \Delta g \cdot \sigma_a$$

$$\sigma_{max} = \sigma_c + \Delta g \cdot \sigma_a$$

The value of σ_c and σ_a are in general different for each segment and are calculated by forming linear combinations of the stress due to the fatigue spectrum conditions (see Table 4-14).

$$\sigma_{cj} = \sum_{i=1}^{6} c_{ij} \sigma_i$$

$$\sigma_{aj} = \sum_{i=1}^{6} a_{ij}\,\sigma_i$$

where i denotes the fatigue spectrum condition number and j denotes the segment number. The constants c_{ij} and a_{ij} are based on the flight profile (see Table 4-12) and are stored within the program.

he ground-air-ground (G-A-G) cycle shown in Figure 4-31 was not previously defined. It dominates fatigue damage and flaw growth in many areas of the structure of transport aircraft. This stress excursion is due in part to the difference between the groundborne load distribution and the airborne distribution, and in part to cabin pressurization. A G-A-G spectrum is calculated automatically within the program at each analysis point. The G-A-G cycle is defined as the maximum stress excursion between the peak inflight stress (i.e., the maximum gust occurring in that flight) and the peak/valley groundborne stress (i.e., the maximum taxi Δg). Several high peaks of cyclic loads, such as those due to gust encounters in stormy weather, tend to occur on the same flight. It would therefore be conservative to use all peak loads expected in the total aircraft life in building the G-A-G spectrum. To avoid this overconservatism a frequency factor is introduced, which has the effect of skipping over some of the peak loads. A frequency factor equal to two is considered appropriate for transport aircraft. Thus, every other peak is included in the G-A-G spectrum. Frequency factor is a user input.

A unique stress spectrum is generated for each structural element based on the local stress history and is used for the fatigue analysis and flaw growth analysis also reported

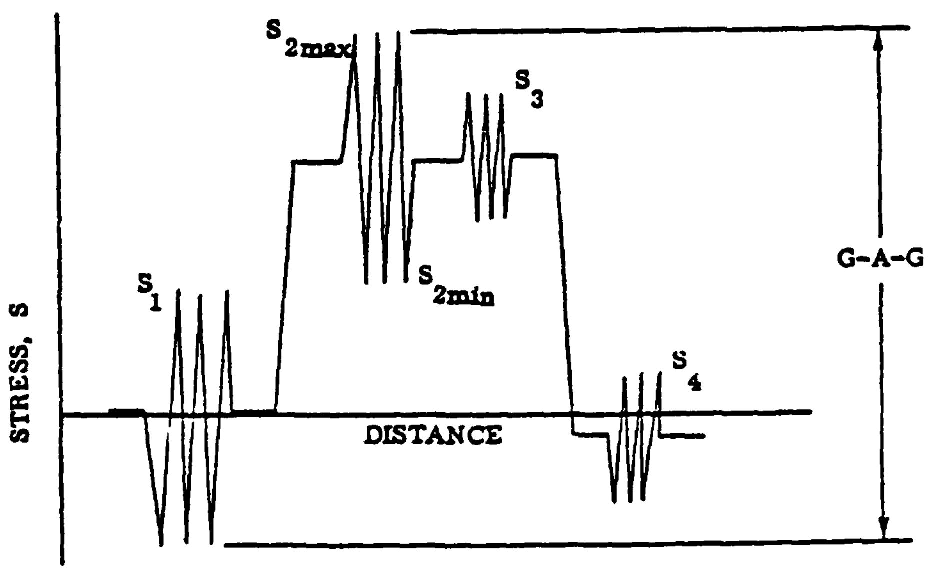


Figure 4-31. Simplified Flight Profile

in this section. No provision is currently available for changing the load profile; however, additional load spectra can be incorporated into the existing program with very little programming effort.

FATIGUE ANALYSIS. Fatigue damage is defined as the ratio of the number of applied stress cycles, n, of a given stress magnitude to the number of allowable stress cycles, N, of the same stress magnitude. Miner's Rule (Reference 12) is the basis of fatigue damage analysis performed by the subroutine, PRODAM. Under this concept, fatigue damage is assumed to be linearly cumulative, and fatigue failure is assumed to occur when the damage summation equals unity.

$$\text{Fatigue Damage} = \frac{n_1}{N_1} + \frac{n_2}{N_2} + \frac{n_3}{N_3} + \cdots \frac{n_m}{N_m}$$

$$\text{Fatigue Failure} = \sum_{i=1}^{m} \frac{n_i}{N_i} = 1$$

To facilitate the analysis. S-N curves are plotted from test data for several values of stress ratio, R. Allowable cycles for each subsegment are read from the curves as shown in Figure 4-32.

where,

$$R = \frac{S_{min}}{S_{max}} \qquad \text{(Also see Figure 2-27)}$$

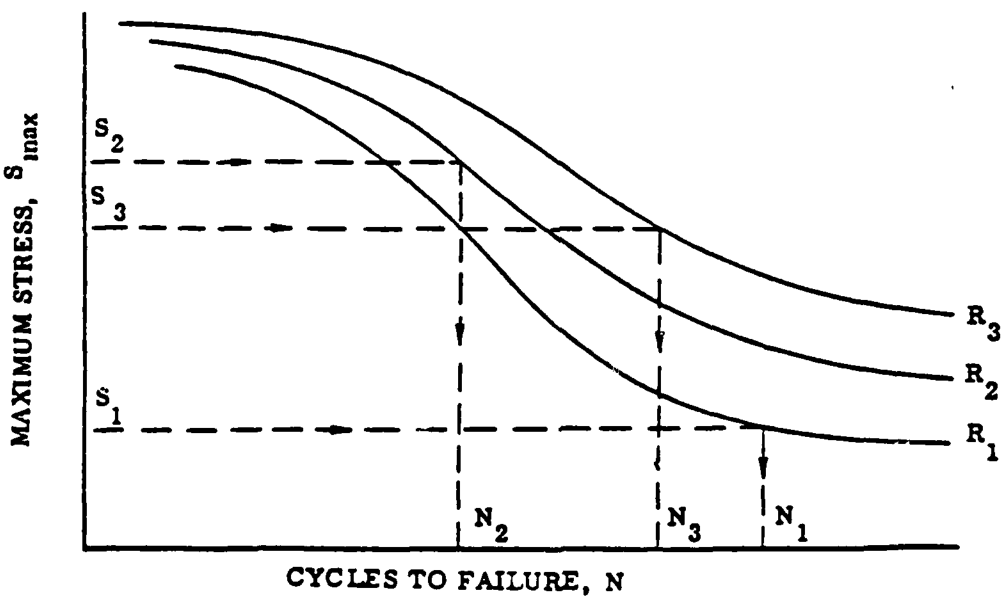


Figure 4-32. Fatigue Damage Determination

A review of previous General Dynamics programs and other sources did not produce nearly enough component S-N data to fill the required data bank indicated by Table 4-20. Much of the data reviewed was generated for specific configurations and load spectra. Manufacturers usually test splices and other fatigue critical details but seldom develop S-N curves for typical structure and spectra. Even less data is published because component test results are frequently considered proprietary or sensitive to a particular project.

Table 4-20. Availability of Fatigue Data

Material	Fabrication Method	Wing Box	Fuselage	General Structure	Coupon S-N
Aluminum	Riveted	◒	◒	●	
	Integral	◒	○	◒	●
	Bonded	○	○	○	
	Welded	○	○	○	
Titanium	Riveted	○	○	○	
	Integral	◒	○	◒	●
	Bonded	○	○	○	
	Welded	○	○	○	
Graphite/ Epoxy	Riveted	○	○	○	
	Integral	○	○	○	◒
	Bonded	○	○	○	
Boron/ Epoxy	Riveted	○	○	◒	
	Integral	○	○	○	◒
	Bonded	○	○	◒	

○ = No data
● = Complete data

In some cases the component data was incomplete. To facilitate extrapolation, curves of stress versus stress ratio at constant cycle values were plotted from the original data. Expanded S-N curves were then drawn based on the extrapolated data. For the many cases where component data was not available, reduction factors were applied to un-notched coupon data for the appropriate material. A complete set of data was generated by this method. However, S-N curves plotted from this data did not show the trends and consistency expected. Anomalies in the component data due to inconsistent test parameters were still present in the expanded S-N curves. A complete and consistent set of S-N curves for all required component types could not be obtained with this approach.

Subsequently, a second method, Reference 11, for plotting S-N curves from limited data was employed. This procedure utilizes two Hewlett-Packard 9100B computer programs to curve fit and plot data. More reliance is placed on un-notched coupon data, and component fatigue notch factors are plotted versus life to ensure that smooth and consistent S-N curves are generated.

Data from constant life cuts of these curves is stored in the program. An interpolation routine is used in the program to retrieve allowable cycles from the stored data.

This rather simple approach is widely used in fatigue life predictions of transport aircraft. The more severe load spectra of fighter type aircraft produce more significant residual stresses at points of stress concentration and may warrant a more sophisticated analytical treatment.

CRACK GROWTH ANALYSIS

The crack growth analysis procedure used in the APAS IV Program predicts how a crack grows under cyclic fatigue spectrum loading. Two basic rate equations are used, one for load steps with positive stress ratios and the other for negative stress ratio load steps. The Walker effective stress concept introduced in the Paris rate equation (Reference 13), serves as the basis for predicting crack growth rates with positive stress ratio load steps. The Chang crack growth rate model (Reference 2) is used for negative stress ratio load steps. Load interaction effects are accommodated by employing the Willenborg effective stress concept with the Chang acceleration scheme. The model is identified as Willenborg/Chang model in Reference 2. These crack growth prediction methods are implemented in subroutines PREGRO, CORREC, CRITIC, CLAMDA and FLTGRO.

Paris formulated a crack growth rate model as a function of the stress intensity factor range, ΔK, and empirical material dependent constants (Reference 14).

$$\frac{da}{dN} = F\,(\Delta K,\ \text{empirical constants})$$

where da/dN is the cyclic growth rate and the stress intensity factor range, ΔK, is a measure of the crack tip stress field (see Figure 4-33)

$$\Delta K = \Delta\sigma\beta(a)\sqrt{\pi a}$$

$$= K_{max} - K_{min}$$

$\Delta\sigma = \sigma_{max} - \sigma_{min}$, range of remotely applied cyclic stresses [psi]

a, half crack length [in.]

$\beta(a)$, correction factor that accounts for geometric effects [dimensionless]

Subsequent to the Paris formulations, results of constant amplitude tests identified variations in crack growth rates due to different stress ratios. Based only on positive stress ratios, Walker introduced the concept of an effective stress, $\bar{\sigma}$.

$$\bar{\sigma} = (1 - k)^m \sigma_{max} \qquad R \geq 0$$

and

$R = {}_{min}/{}_{max}$

m = stress ratio collapsing constant

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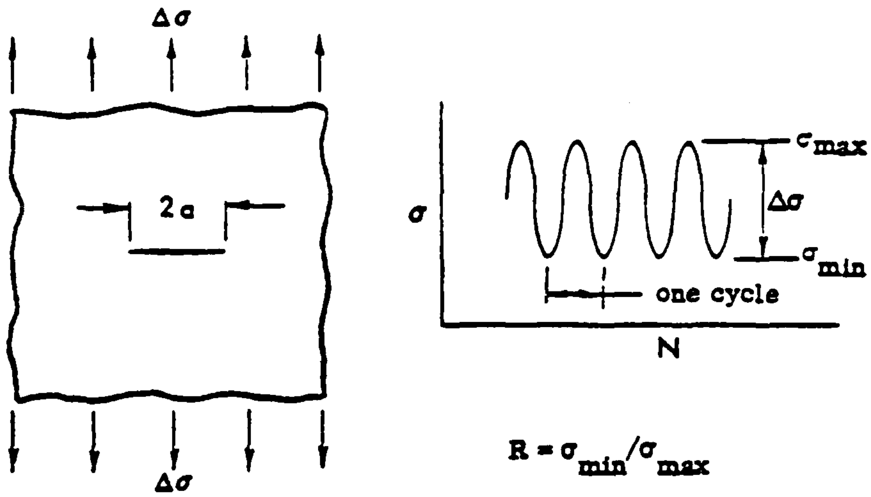

Figure 4-33. Fatigue Crack Loading

The following rate equation is obtained by using the Paris model with the Walker effective stress.

$$\frac{da}{dN} = F(\bar{\Delta}K, \text{ empirical constants})$$

$$= C(\bar{\Delta}K)^n$$

$$= C[(1 - R)^m \sigma_{max} \beta(a) \sqrt{\pi a}]^n$$

$$= C[(1 - R)^m K_{max}]^n$$

$$= C[(1 - R)^{m-1} \Delta K]^n \qquad R \geq 0$$

where C and n are empirical constants determined from constant amplitude tests.

Based on the observation of the differences between constant amplitude tension-compression cyclic test results and R = 0 data, in Reference 2, Chang proposed a rate equation which correlates crack growth behavior due to negative stress ratio cyclic loading. The equation form is:

$$\frac{da}{dN} = C[(1 + R^2)^q K_{max}]^n \quad , \qquad R < 0$$

where C and n are the same constants as that for the positive stress ratio rate equation and q is the acceleration index which is determined by tension-compression cyclic test for a specific value of negative stress ratio.

For low stress intensity factor ranges, crack growth rates are reduced and at a threshold stress intensity factor range, ΔK_{TH}, no discernible growth is observed. This characteristic is accounted for by considering zero growth when the stress intensity factor range is equal to or less than the threshold value.

$$\frac{da}{dN} = 0\,, \qquad \Delta K \le \Delta K_{TH}$$

where $\Delta K_{TH} = \Delta K_{TH_O}\,(\,|\text{-}A\,|R\,|)$ and ΔK_{TH_O} is the threshold value of ΔK at $R = 0$, A is a material dependent constant.

The foregoing rate equations characterize subcritical crack growth behavior under constant amplitude cyclic loading. However, application of these equations to variable amplitude spectrum loadings have been shown to result in significant differences between predicted lives and actual test results. The occurrence of tensile overloads have been shown to retard the crack growth on subsequent load steps. Compressive load immediately following the tensile overload reduces the retardation effect. The Willenborg/Chang scheme was selected to account for these load interaction effects. The method is based on defining effective stress, σ_{eff}, effective stress intensity factor, K_{eff}, and the effective stress ratio, R_{eff}, to model the interaction effects. The following paragraphs describe the Willenborg/Chang load interaction model briefly:

The plane stress plastic zone, Z_{OL}, at the crack tip due to a tensile overload is given by:

$$Z_{OL} = \frac{1}{2\pi}\left(\frac{K_{max}^{OL}}{f_{ty}}\right)^2\,, \qquad R_{OL} \ge 0$$

where f_{ty} is the material tensile yield stress [psi].

When the tensile overload is followed by a compressive load, the Chang scheme considers a reduced effective plastic zone as shown below.

$$Z_{OL} = \frac{1}{2\pi}\left(\frac{K_{max}^{OL}}{f_{ty}}\right)^2\left(1 + R_{OL}\right)\,, \qquad R_{OL} < 0$$

The plastic zone radius, r_{OL}, due to the overload step is depicted in figure 4-34.

$$r_{OL} = a_{OL} + Z_{OL}$$

where a_{OL} is the half crack length following the overload step.

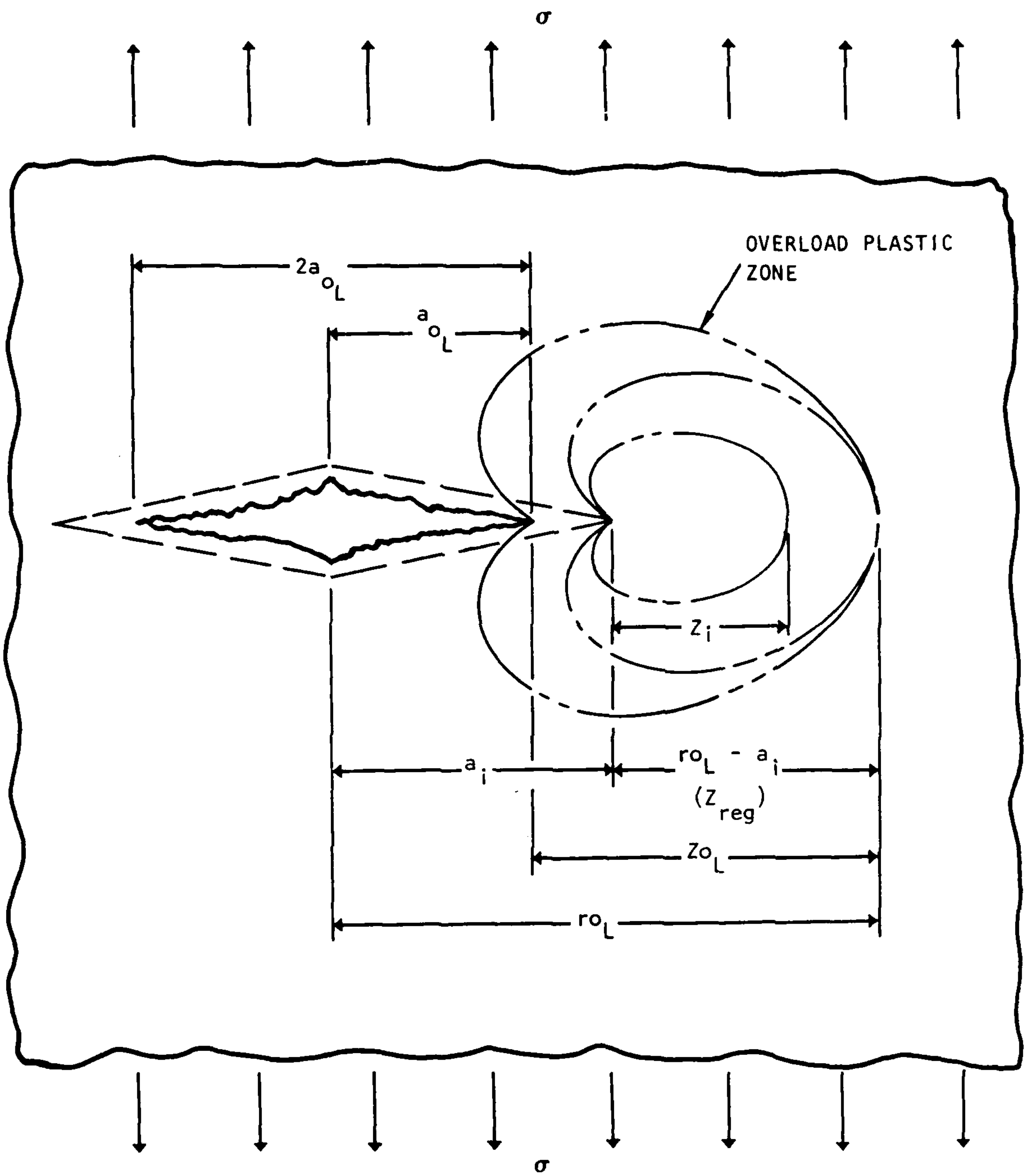

Figure 4-34. Fatigue Crack-Growth Load Interaction Model Based on Plastic Zone Size

On any subsequent load step, i, crack growth is considered to be affected by the residual plastic zone radius, r_{OL}, if the plastic zone for that step, r_i, lies within that resulting from the overload condition. The Willenborg model identified an effective stress parameter based on the stress required, σ_{req} to break through the overload plastic zone.

$$Z_{req} = r_{OL} - a_i = \frac{1}{2\pi}\left(\frac{\sigma_{req}\lambda(a)\sqrt{\pi a_i}}{f_{ty}}\right)^2$$

$$\sigma_{req} = \frac{f_{ty}\sqrt{2\pi\,(r_{OL} - a_i)}}{\lambda(a)\,\sqrt{\pi a}}$$

Gallagher modified the Willenborg retardation model by introducing a proportionality constant, ϕ. The effective stress is then defined as a measure of the difference between the stress required to penetrate the residual overload plastic zone and the actual spectrum stress (Reference 15).

$$\sigma_{max\ eff} = \sigma_{max} - \phi\left(\sigma_{req} - \sigma_{max}\right)$$

$$\sigma_{min\ eff} = \sigma_{min} - \phi\left(\sigma_{req} - \sigma_{max}\right)$$

and the proportionality constant, ϕ, is defined as:

$$\phi = \frac{1 - \frac{\Delta K_{TH}}{K_{max}}}{R_{shut} - 1}$$

where R_{shut} shutoff ratio, material dependent constant.

The effective maximum and minimum stress intensity factors and corresponding effective stress ratio are defined as

$$\left(K_{max}\right)_{eff} = \left(\sigma_{max}\right)_{eff}\ \beta(a)\ \sqrt{\pi a}$$

$$\left(K_{min}\right)_{eff} = \left(\sigma_{min}\right)_{eff}\ \beta(a)\ \sqrt{\pi a}$$

and

$$R_{eff} = \left(\sigma_{min}\right)_{eff} / \left(\sigma_{max}\right)_{eff} \qquad R^{-}_{cut} \le R_{eff} \le R^{+}_{cut}$$

$$\Delta K = K_{max} - K_{min} = \left(K_{max}\right)_{eff} - \left(K_{min}\right)_{eff}$$

where

R^{-}_{cut} = negative stress ratio cutoff value

R^{+}_{cut} = positive stress ratio cutoff value

Thus due to load interaction effects, the crack growth rate equations are:

$$\frac{da}{dN} = C\left[\left(1 - R_{eff}\right)^{m-1} \Delta K\right]^{n}, \qquad R_{eff} \ge 0$$

$$\frac{da}{dN} = C\left[\left(1 + R^{2}_{eff}\right)^{q} \left(K_{max}\right)_{eff}\right]^{n}, \qquad R_{eff} < 0$$

$$\frac{da}{dN} = 0 , \qquad \Delta K \le \Delta K_{TH}$$

The damage accumulation scheme used to predict crack growth life consists of a three-step procedure performed by PREGRO and subroutines CLAMDA and FLTGRO. In the first step, PREGRO uses the Vroman linear approximation method for a unit-block flight spectrum to obtain crack growth rate per flight $(da/dF)_j$ and a measure of the stress intensity factor K_j for j values of initial crack size. The second step consists of using a least-square-fit procedure for the $(da/dF)_j$ versus K_j values to characterize an equivalent growth per flight rate equation in subroutine FLTGRO uses the crack growth per flight rate equation to calculate crack growth life.

The linear-approximation method assumes that the growth rate is constant throughout a load step in a spectrum so that the crack size is in a linear relationship with the number of load cycles. The damage accumulation scheme proceeds by considering a load step (i) and using σ_{max_i} and σ_{min_i} to calculate da/dN. The relatively small incremental change in crack length, δa, of 0.01a is used to provide reasonable computational accuracy in the following procedure (Reference 16).

The value of $(\delta a)/(da/dN)$ is then compared to the cycles in that load step, N_i, where "a" is the crack size. If $(\delta a)/(da/dN)$ is greater than N_i, then the crack growth for that particular load step is $\Delta a = N_i \times (da/dN)$; "a" is increased by Δa, and the program proceeds to the next load step.

If $(\delta a)/(da/dN)$ is less than or equal to N_i, then the number of cycles to grow (δa) is $(\delta a)/(da/dN)$. This value is subtracted from N_i, the crack size "a" is increased by (a), and the load step is reconsidered. This process continues with $(\delta a)/(da/dN)$ being compared to the remaining cycles in the step. The process is repeated until all load steps in the block (or flight) are exhausted.

The cycle-by-cycle crack growth analysis is performed for a unitblock load spectrum for j values of initial crack size. The crack growth rate resulting from the unitblock spectrum defined for a period of N_A flights is then equal to the crack growth Δa_j divided by N_A.

$$\left(\frac{da}{dF}\right)_j = \frac{\Delta a_j}{N_A}$$

The second step in the computational procedure consists of characterizing the flaw growth for the complex flight spectra into an equivalent constant-amplitude loading that will produce the same crack growth life. This method is based on the observation of crack growth rate per flight as a function of a measure of the stress intensity factor, K, representing the unitblock spectrum. This relationship is:

$$\frac{da}{dF} = C(\bar{K})\lambda$$

and

$$\bar{K} = \left(\overline{\Delta\sigma^2}\right)^{1/2} \beta(a) \sqrt{\pi a}$$

where $(\overline{\Delta\sigma^2})^{1/2}$ is the root-mean-square of the stress range history.

The power exponent λ and the growth rate constant C are calculated in subroutine CLAMDA by applying a least-square-fit procedure to the log $(da/dF)_j$ versus log $(\bar{K}_j)$ data plot.

In the third step, subroutine FLTGRO uses the linear-appr· :imation method on the crack growth per flight rate equation to determine the crack growth over the prescribed crack length interval.

The foregoing procedure is applicable to any flaw geometry for which the stress intensity correction factors, β, are known. The program currently contains factors for a wide range of stiffened panels with through cracks. Curves for L(a) and β(a) for the case of a crack extending equally on both sides of a riveted stiffener (illustrated in Figure 4-35 are stored within the program in the form of data tables. For further information concerning the derivation of these curves the reader is referred to Reference 17.

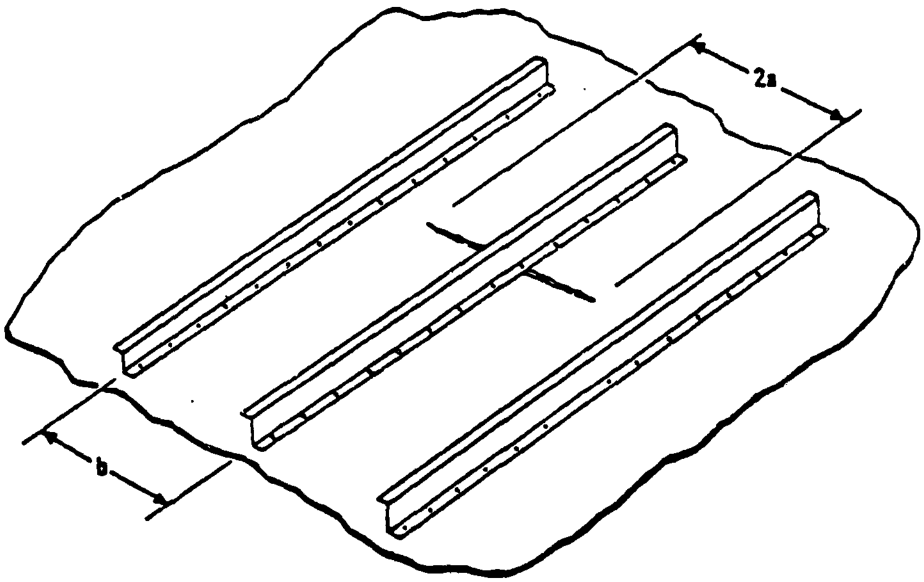

Figure 4-35. Stiffened panel crack geometry.

The program currently contains 75 sets of data for L(a) and β(a) covering a wide range of stiffener spacing and percent stiffening, including cases for broken stiffeners. Figure 4-36 presents a typical set of curves. Linear interpolation is used to determine L(a) and β(a) curves for cases that lie between data sets. These curves are used for all riveted-stiffener plate combinations, (e.g., panel types 4 through 9 of Figure 4-4).

For the case of integral construction (e.g., panel types 1, 2, and 3), the panel is treated as a flat plate without stiffeners with a thickness equal to t (i.e., β(a) = 1.0).

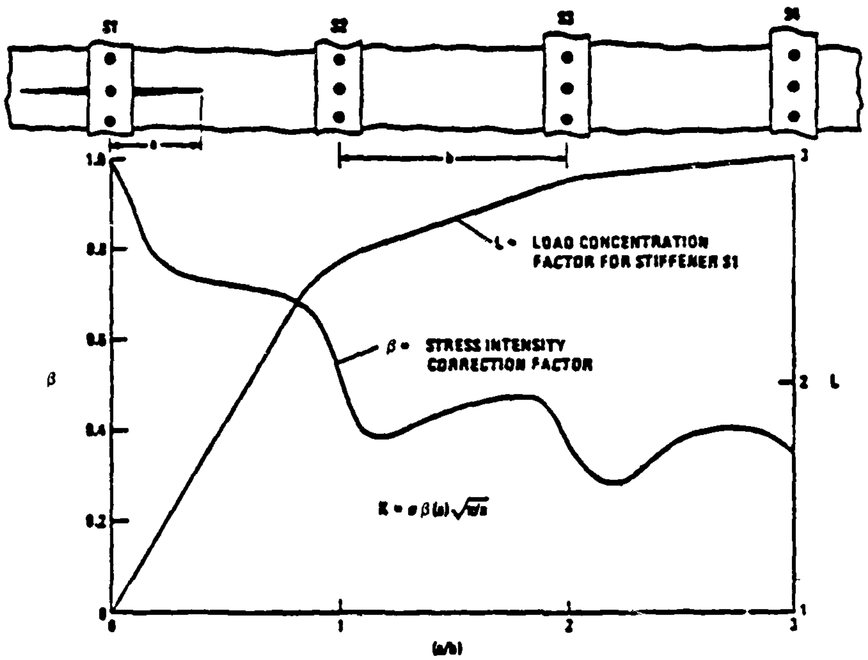

Figure 4-36. Stiffened panel stress intensity correction factors.

For all stiffened panel types (types 1 through 9), panel half width is assumed to be equal to 10 stiffener spacings, and the stress intensity correction is revised to include the width correction factor.

$$\beta(a) = L(a)\left[1 - 0.025\left(\frac{a}{\omega}\right)^2 + 0.06\left(\frac{a}{\omega}\right)^4\right]\sqrt{\sec\left(\frac{\pi a}{\omega}\right)}$$

where ω is the panel half width [in.]

On plate construction types (types 10 and 11), no adjustment is made for panel width and $\beta(a) = 1.0$. For plate concepts crack life is based on crack growth from an initial length to a critical flaw size.

RESIDUAL STRENGTH ANALYSIS

The residual strength analysis determines the failing strength of a damaged panel and is performed by subroutine RESID. Damage consists of skin cracks and broken

stiffeners. The residual strength of a damaged panel is defined as the maximum stress level that can be applied to the panel without the crack growing unstably to failure. Unstable crack growth occurs when the applied stress intensity factor, K, exceeds the fracture toughness of the skin material, K_C.

Unstable crack growth is allowed to occur at stress levels below the residual strength of a panel as long as the crack growth eventually arrests at a larger crack size. Whenever stress level of the most highly loaded stiffener exceeds the ultimate tensile strength of the stiffener, it fails, and the applied stress intensity factors of the skin are recalculated to reflect the broken stiffener.

Figure 4-37 illustrates a typical example of the residual strength analysis procedure. The curves shown are generated by calculating the gross panel stress that causes stiffener failure and the gross panel stress that cause unstable crack growth. The following equations are used for these calculations.

$$\sigma_{cr\,(\text{unstable crack growth})} = \frac{K_C\ (\text{sheet})}{\beta(a)\ \sqrt{\pi a}}$$

$$\sigma_{cg}\ (\text{stiffener failure}) = \frac{F_{tu}\ (\text{stiffener})}{L(a)}$$

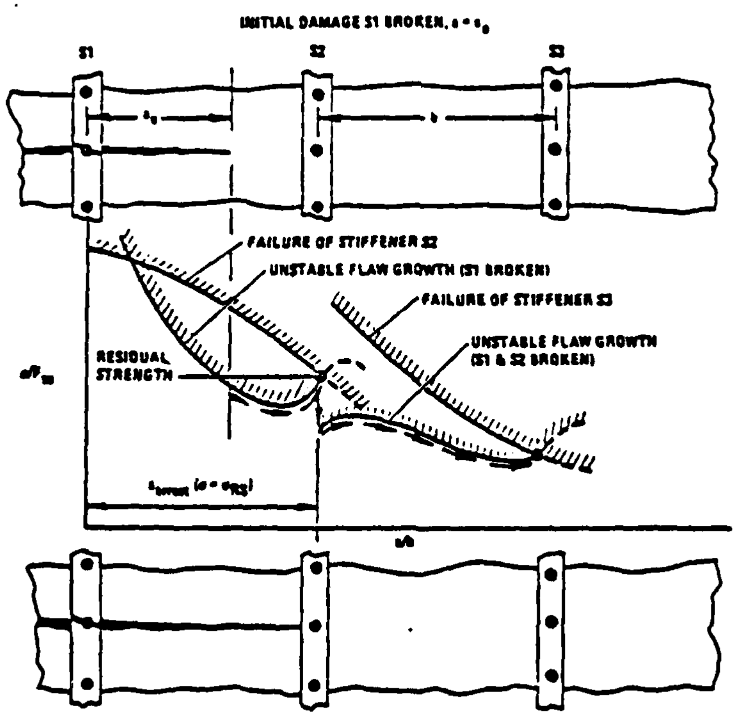

Figure 4-37. Typical example of residual strength analysis.

4.1.4 DECK STRUCTURE. The input data deck for APAS is described in this section. The overall deck setup is shown in Figure 4-38.

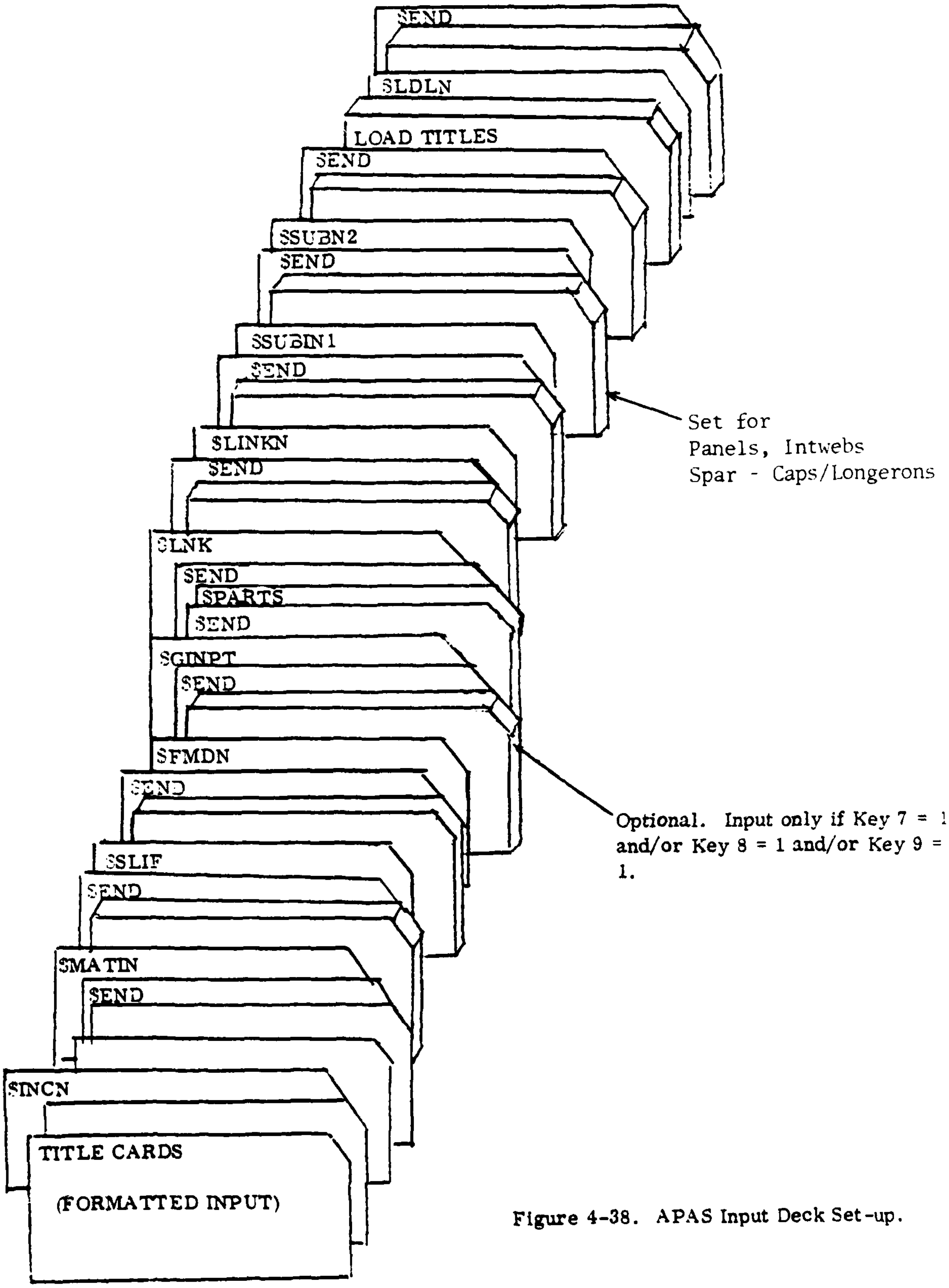

Figure 4-38. APAS Input Deck Set-up.

4.1.5 RELATIONSHIP OF INPUT TO OUTPUT. A representative input data listing for the APAS program is shown in Figure 4-39. The input is entered through the NAMELIST capability as discussed in sections 4.1.1 and 4.1.2. The results of the analysis are printed out (see Section 4.2) and also stored on a series of output files which may be later accessed by parts prediction and cost routines.

```
***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
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$INCN
IT1      = 0.
IT2      = 0.
IT3      = 0.
IT4      = 0.
EPS1     = 0.0.
EPS2     = 0.0.
EPS3     = 0.0.
EPS4     = 0.0.
KEY1     = 1.
KEY2     = 1.
KEY3     = 1.
KEY4     = 30.
KEY5     = 0.
KEY6     = 0.
KEY7     = 1.
KEY8     = 1.
KEY9     = 1.
KEY10    = 1.
KEY11    = 1.
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MATIO    = 4. 6. 8. 0. 0. 0.
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$END
$LIF
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FREQ     = .2E+01.
ASUBO    = 1.E+00.
FLTFG    = .2E+05.
MSUBD    = 1.
ASUBD    = 7.5.
CRS      = .85E+00.
MSUBDL   = 0.
ASUBDL   = 0.0.
CRSL     = 0.0.
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IDPROC = 0.
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$FMON
IFM      = 0. 0. 0.
$END
$GINPT
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FRSP  =  10*20.. 10*0.0.
XLCRF =  160.59.  144.05.  127.51.  110.98.   94.44.  83.42. 72.41.
         61.39.   50.36.   39.36.  10*0.0.
ZLDNF =  20*0..
GX    =  64.23.  57.62.  51.01.  44.35.  37.7 .  33.37. 28.56. 24.56.
         20.15.  15.75.  10*0.. 112.41. 100.84.  89.26. 77.68. 66.11.
         58.40.  50.68.  42.90.  35.26.  27.55. 10*0..
         160.59. 144.05. 127.51. 110.98. 94.44. 83.43.72.41.61.39.50.38.
         39.36. 10*0..
         208.76. 187.27.165.77.144.2 .122.77.106.45.94.13.79.81.65.49.
         51.17. 10*0..
         256.94. 230.46. 204.02. 177.56. 151.06. 133.48. 115.86.98.23.
         80.60.  62.98. 10*0..
         256.94. 230.46. 204.02. 177.56. 151.06. 133.48. 115.86.98.23.
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         35.26. 27.55. 10*0..
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         20.15. 16.75. 210*0..
```

Figure 4-39. APAS Input Listing

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         35.59,  30.95,  26.32,  21.65,  17.0 ,  14.66,  12.27,  9.88,
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GTRZ   =  20*0.,
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CX1 = 0.,
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NSGJ     = 0,
NSGL     = 2,
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TMN      = .8E-01, .8E-01, .4E-01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,   0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
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BMN      = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           0.0, .4E+00, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,   0.0, 0.0, 0.0, 0.0, 0.0, 0.0, .1E+00,
           .1E-01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,   0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
BMX      = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           0.0, .2E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,   0.0, 0.0, 0.0, 0.0, 0.0, 0.0, .1E+01,
           .3E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,   0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
$END
$SUBIN1
ITYPE    = 2, 2, 0, 0, 0,
IDSET    = 1, 1, 0, 0, 0,
IDMAT1 = 3, 3, 0, 0, 0,
IDMAT2 = 5*0,
FELEM    = 0.0, 0.0, 0.0, 0.0, 0.0,
T        = .1E+00, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,   0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           .1E+00, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,   0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           .1E+00, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,   0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
TMN      = .4E-01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,   0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           .4E-01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,   0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           .4E-01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,   0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
B        = .15E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,   0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           .15E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,   0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           .15E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,   0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
BMN      = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,   0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,   0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,   0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
BMX      = .25E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,   0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           .25E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,   0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           .25E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,   0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
$END
$SUBN2
IFT      = 3,
IDMTFR   = 1,
$END
```

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2.56 POSITIVE MANEUVER S-4 WING
-1.0G NEGATIVE MANEUVER S-4 WING
2.0G TAXI S-4 WING
1.0G FLIGHT S-4 WING
1.0G TAXI S-4 WING
1.0G FLIGHT S-4 WING
1.0G FLIGHT +1.0G GUST S-4 WING
1.0G FLIGHT PLUS 1.0G MAN. S-4 WING
1.0G LANDING IMPACT S-4 WING
MAXIMUM CABIN PRESSURE S-4 WING

$LDLN
NCOND  = 4,
NSPLC  = 6,
FBUCK  = .4E+00,
FULT   = .15E+01,
NSTAY  = 10, 10, 10, 10, 10, 10, 10, 10, 10, 2,
PRES   = 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
FLIM   = 1123.9, 1123.9, 1123.9, 1123.9, 1123.9,                    1123.9, 1123.9, 1123.9,
         1123.9, 1123.9,
FLD    = .667E+00, .667E+00, .667E+00, .667E+00, .667E+00, .667E+00, .667E+00, .667E+00, .667E+00, .667E+00,
FA     = .1E+01, .1E+01, .1E+01, .1E+01, .1E+01, .1E+01, .1E+01, .1E+01,      .1E+01, .1E+01,
FXS    = .1E+01, .1E+01, .1E+01, .1E+01, .1E+01, .1E+01, .1E+01, .1E+01,      .1E+01, .1E+01,
FZS    = .1E+01, .1E+01, .1E+01, .1E+01, .1E+01, .1E+01, .1E+01, .1E+01,      .1E+01, .1E+01,
FTOR   = .1E+04, .1E+04, .1E+04, .1E+04, .1E+04, .1E+04, .1E+04, .1E+04,      .1E+04, .1E+04,
FXM    = .1E+04, .1E+04, .1E+04, .1E+04, .1E+04, .1E+04, .1E+04, .1E+04,      .1E+04, .1E+04,
FZM    = .1E+04, .1E+04, .1E+04, .1E+04, .1E+04, .1E+04, .1E+04, .1E+04,      .1E+04, .1E+04,
FTEMP  = .1E+01, .1E+01, .1E+01, .1E+01, .1E+01, .1E+01, .1E+01, .5E+00,      .1E+01, .1E+01,
STA    = 0.0, .991E-01, .1964E+00, .32613E+00, .3265E+00, .38829E+00,      .38838E+00, .72523E+00, .72532E+00,
         .1E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,      .991E-01, .1964E+00, .32613E+00, .3265E+00,
         .38829E+00, .38838E+00, .72523E+00, .72532E+00, .1E+01, 0.0, 0.0,      0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, .991E-01, .1964E+00, .32613E+00, .3265E+00, .38829E+00,      .38838E+00, .72523E+00, .72532E+00,
         .1E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,      .991E-01, .1964E+00, .32613E+00, .3265E+00,
         .38829E+00, .38838E+00, .72523E+00, .72532E+00, .1E+01, 0.0, 0.0,      0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, .991E-01, .1964E+00, .32613E+00, .3265E+00, .38829E+00,      .38838E+00, .72523E+00, .72532E+00,
         .1E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,      .991E-01, .1964E+00, .32613E+00, .3265E+00,
         .38829E+00, .38838E+00, .72523E+00, .72532E+00, .1E+01, 0.0, 0.0,      0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, .991E-01, .1964E+00, .32613E+00, .3265E+00, .38829E+00,      .38838E+00, .72523E+00, .72532E+00,
         .1E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,      .991E-01, .1964E+00, .32613E+00, .3265E+00,
         .38829E+00, .38838E+00, .72523E+00, .72532E+00, .1E+01, 0.0, 0.0,      0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, .991E-01, .1964E+00, .32613E+00, .3265E+00, .38829E+00,      .38838E+00, .72523E+00, .72532E+00,
         .1E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,      .1E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,      0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,      0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
AXL    = -.2286E+05, -.2286E+05, -.1851E+05, -.1465E+05, -.1477E+05,      -.1321E+05, -.1251E+05, -.4275E+04,
         -.3577E+04, -.6035E+03, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,      0.0, .4019E+04, .4019E+04, .1641E+04,
         -.1036E+03, -.1265E+04, -.202E+04, .19E+04, -.217E+04, .185E+04, .35E+03,      0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, -.147E+05, -.147E+05, -.1112E+05, -.838E+04,      -.737E+04, -.662E+04, -.551E+04, -.211E+04,
         -.59E+03, -.8E+02, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,      -.726E+04, -.726E+04, -.651E+04, -.62E+04,
         -.667E+04, -.656E+04, -.345E+04, -.312E+04, -.3E+02, -.2E+02, 0.0,      0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, -.735E+04, -.735E+04, -.556E+04, -.419E+04, -.3665E+04,      -.331E+04, -.2755E+04, -.1055E+04,
         -.495E+03, -.4E+02, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,      -.72E+04, -.725E+04, -.651E+04, -.62E+04,
         -.667E+04, -.656E+04, -.345E+04, -.312E+04, -.3E+02, -.2E+02, 0.0,      0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, -.1406E+05, -.1405E+05, -.11994E+05, -.10398E+05,      -.10935E+05, -.10301E+05, -.6917E+04,
         -.4062E+04, -.668E+03, -.67E+02, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,      0.0, 0.0, 0.0, -.17672E+05, -.17672E+05,
         -.14507E+05, -.11937E+05, -.12073E+05, -.10996E+05, -.9503E+04,      -.3898E+04, -.2346E+04, -.405E+03, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, -.735E+04, -.735E+04,      -.556E+04, -.419E+04, -.3665E+04, -.331E+04,
         -.2755E+04, -.1055E+04, -.495E+03, -.4E+02, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,      0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,      0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,      0.0, 0.0,
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XSF    = -.115E+03, -.115E+03, -.3035E+04, -.2437E+04, -.1094E+04, -.1228E+04,
         -.727E+03, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         -.101E+05, -.101E+05, -.302E+04, -.499E+04, .228E+04, .453E+03, 0.0,
         0.0, 0.0, .1414E+05, .1414E+05, .117E+05, .806E+04, .279E+04,
         .1E+03, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, -.225E+04,
         -.481E+04, -.125E+04, -.323E+04, .23E+03, .1E+02, 0.0, 0.0, 0.0, 0.0,
         .707E+04, .535E+04, .403E+04, .439E+04, .395E+04, .3285E+04,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, -.225E+04, -.225E+04,
         -.125E+04, -.333E+04, .23E+03, .1E+02, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         -.5417E+04, -.5997E+04, -.4557E+04, -.5343E+04, -.2354E+04,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, -.826E+03, -.826E+03,
         -.2421E+04, -.3631E+04, -.2139E+04, -.2749E+04, -.482E+03, 0.0, 0.0,
         0.0, .707E+04, .707E+04, .535E+04, .403E+04, .4395E+04, .395E+04,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
ZSF    = .1144E+06, .1144E+06, .1173E+06, -.3173E+05, .9466E+05, .8661E+05,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, -.3561E+05,
         -.371E+05, -.439E+05, -.218E+05, -.286E+05, -.57E+04, 0.0, 0.0, 0.0,
         -.1597E+06, -.1597E+06, -.1208E+06, -.9106E+05, -.6483E+05,
         -.1209E+05, -.99E+03, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         .1573E+05, .1613E+05, .121E+05, .1564E+05, -.215E+04, .239E+04,
         0.0, 0.0, 0.0, 0.0, 0.0, -.7965E+05, -.7985E+05, -.604E+05,
         -.33555E+05, -.1285E+05, -.6045E+04, -.495E+03, 0.0, 0.0, 0.0, 0.0, 0.0,
         .3255E+05, .24E+05, .1573E+05, .1613E+05, .121E+05, .1564E+05,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, .5885E+05, .58835E+05,
         .34015E+05, .43179E+05, .7446E+04, .16603E+05, .2057E+04, 0.0, 0.0,
         0.0, .87144E+05, .87144E+05, .87563E+05, .6734E+05, .68505E+05,
         .36814E+05, .601E+04, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         -.4554E+05, -.44915E+05, -.40355E+05, -.33555E+05, -.1285E+05,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0,
TORQ   = .3266E+03, .3266E+03, -.1507E+04, -.3019E+04, .3226E+03, .547E+02,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, -.2839E+04,
         -.3571E+04, -.311E+04, -.3387E+04, -.2694E+03, -.9493E+03,
         0.0, 0.0, 0.0, 0.0, 0.0, -.286E+02, -.286E+02, -.3762E+03,
         -.7676E+03, -.11136E+04, .566E+02, .46E+01, 0.0, 0.0, 0.0, 0.0, 0.0,
         -.346E+04, -.4037E+04, -.3443E+04, -.3445E+04, -.3198E+04,
         -.42E+02, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, -.14E+02,
         -.1144E+04, -.364E+03, -.555E+03, .29E+02, .2E+01, 0.0, 0.0, 0.0,
         -.346E+04, -.346E+04, -.4037E+04, -.3943E+04, -.3445E+04, -.3198E+04,
         -.42E+02, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         -.2998E+04, -.2667E+04, -.2525E+04, -.1516E+04, -.1101E+04,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, -.934E+03, -.934E+03, -.2349E+04,
         .157E+03, -.721E+03, .147E+03, .2E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         -.186E+03, -.345E+03, -.1177E+04, -.1144E+04, -.364E+03, -.555E+03,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0,
XMOM   = .4561E+05, .4561E+05, .4066E+05, .3069E+05, .3082E+05, .2676E+05,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, -.1987E+05,
         -.1288E+05, -.1144E+05, -.1132E+05, -.2875E+04, -.2835E+04,
         0.0, 0.0, 0.0, 0.0, 0.0, -.3731E+0 , -.3731E+05, -.267E+05,
         -.1285E+05, -.4034E+03, -.1141E+04, -.275E+02, 0.0, 0.0, 0.0, 0.0,
         .6646E+04, .6618E+04, .4325E+04, .4717E+04, .3894E+04, .334E+04,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, -.18655E+05, -.18655E+05,
         -.598E+04, -.425E+04, -.202E+03, -.57E+03, -.14E+02, 0.0, 0.0, 0.0,
         .6646E+04, .6646E+04, .6618E+04, .4325E+04, .4717E+04, .3694E+04,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, .2074E+05,
         .12184E+05, .1314E+05, .776E+04, .2399E+04, .1913E+04, .1E+03, 0.0,
         0.0, 0.0, .3572E+05, .35502E+05, .29324E+05, .2191E+05, .2212E+05,
         .4049E+04, .173E+03, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         -.602E+04, -.7945E+04, -.598E+04, -.6425E+04, -.202E+03, -.57E+03,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
         0.0, 0.0,
```

```
XSF:
-.3921E+04, -.1545E+04, -.4236E+04,
-.959E+04, -.955E+04, -.962E+04, -.102E+05,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
.79E+04, .657E+04, .291E+04, .116E+04,
-.22E+04, -.377E+04, -.44E+04, -.431E+04,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, .707E+04,
.1255E+04, .59E+03, .5E+02, 0.0, 0.0,
-.377E+04, -.496E+04, -.431E+04, -.481E+04,
0.0, 0.0, 0.0, 0.0, -.3268E+04, -.3288E+04,
-.3425E+04, -.427E+03, -.47E+02, 0.0,
-.327E+04, -.3277E+04, -.2165E+04,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
.3245E+04, .1255E+04, .59E+03, .5E+02,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,

ZSF:
.1036E+06, .17E+05, .54E+05, .92E+04,
-.35611E+05, -.414E+05, -.377E+05, -.383E+05,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
-.86071E+05, -.6711E+05, -.297E+05,
0.0, .3255E+05, .3255E+05, .26E+05,
-.38E+03, 0.0, 0.0, 0.0, 0.0, 0.0,
.4554E+05, .44915E+05, .40355E+05,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, .3255E+05,
.215E+04, .239E+04, -.38E+03, 0.0,
.56655E+05, .393E+05, .4016E+05,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
.6179E+05, .74642E+05, .23963E+05,
0.0, -.7985E+05, -.7985E+05, -.604E+05,
-.6045E+04, -.455E+03, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,

TORQ:
.1451E+04, -.4355E+03, .4825E+03, .489E+02,
-.2839E+04, -.2505E+04, -.2156E+04,
-.1602E+03, 0.0, 0.0, 0.0, 0.0, 0.0,
-.6909E+03, -.2355E+04, -.2284E+04,
0.0, 0.0, 0.0, 0.0, 0.0, -.346E+04,
-.2314E+04, -.1292E+04, -.526E+03,
-.14E+02, -.186E+03, -.345E+03, -.1177E+04,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
-.2314E+04, -.1292E+04, -.526E+03,
-.3076E+04, -.3076E+04, -.2815E+04,
-.328E+03, -.63E+02, 0.0, 0.0, 0.0,
-.3327E+04, -.932E+03, -.1002E+04,
0.0, 0.0, 0.0, 0.0, -.14E+02, -.14E+02,
.29E+02, .2E+01, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,

XMOM:
.2601E+05, .6418E+04, .5866E+04, .235E+03,
-.1987E+05, -.1662E+05, -.1319E+05,
-.613E+02, 0.0, 0.0, 0.0, 0.0, 0.0,
-.1564E+05, -.1556E+05, -.1196E+05,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, .6646E+04,
.913E+03, .411E+03, .48E+02, 0.0, 0.0,
-.1335E+05, -.802E+04, -.7545E+04,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
.334E+04, .913E+03, .411E+03, .48E+02,
.2074E+05, .16673E+05, .1161E+05,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
.1914E+05, .18461E+05, .4585E+04,
0.0, -.18655E+05, -.18655E+05, -.1335E+05,
-.14E+02, 0.0, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
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ZMOM     = -.2119E+04, -.2119E+04, -.2026E+04, -.1762E+04, -.1757E+04,
           -.4676E+03, -.204E+02, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           -.1271E+04, -.1274E+04, -.803E+03, -.609E+03, .295E+03, .275E+03,
           0.0, 0.0, 0.0, 0.0, 0.0, .3301E+04, .3501E+04, .2324E+04, .1357E+04,
           .1164E+03, .31E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           -.1145E+04, -.1144E+04, -.528E+03, -.784E+03, -.89E+02, .1E+02,
           0.0, 0.0, 0.0, 0.0, .165E+04, .165E+04, .1164E+04, .678E+03,
           .5E+02, .2E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           -.1145E+04, -.1144E+04, -.528E+03, -.784E+03, -.84E+02, .18E+02,
           0.0, 0.0, 0.0, 0.0, -.23E+04, -.23E+04, -.1967E+04, -.1421E+04,
           -.149E+03, -.44E+02, -.1E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           -.1557E+04, -.1557E+04, -.1438E+04, -.1274E+04, -.439E+03, -.319E+03,
           0.0, 0.0, 0.0, 0.0, 0.0, .165E+04, .165E+04, .1164E+04, .678E+03,
           .5E+02, .2E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
TEMP     = .8E+02, .8E+02, .8E+02, .8E+02, .8E+02, .8E+02, .8E+02, .8E+02,
           0.0, 0.0, 0.0, 0.0, 0.0, 0.0, .8E+02, .8E+02, .8E+02, .8E+02, .8E+02,
           0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, .8E+02, .8E+02,
           .8E+02, .8E+02, .8E+02, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           .8E+02, .8E+02, .8E+02, .8E+02, .8E+02, .8E+02, 0.0, 0.0, 0.0, 0.0,
           .8E+02, .8E+02, .8E+02, .8E+02, .8E+02, .8E+02, .8E+02, .8E+02,
           0.0, 0.0, 0.0, 0.0, .8E+02, .8E+02, .8E+02, .8E+02, .8E+02, .8E+02,
           0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, .8E+02, .8E+02, .8E+02,
           .8E+02, .8E+02, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           .16E+03, .16E+03, .16E+03, .16E+03, .16E+03, .16E+03, 0.0, 0.0, 0.0,
           .8E+02, .8E+02, .8E+02, .8E+02, .8E+02, .8E+02, .8E+02, .8E+02,
           0.0, 0.0, 0.0, 0.0, 0.0, 0.0, .8E+02, .8E+02, 0.0, 0.0, 0.0, 0.0,
           0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
           0.0, 0.0, 0.0, 0.0, 0.0,
&END

-.1693E+04, -.1518E+04, -.613E+03,
0.0, -.3024E+04, -.3024E+04, -.2282E+04,
.132E+02, 0.0, 0.0, 0.0, 0.0, 0.0,
.1362E+04, .462E+03, .1194E+04, -.516E+02,
-.1794E+04, -.1794E+04, -.1578E+04,
.1E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
.681E+03, .491E+03, .597E+03, -.26E+02,
-.1794E+04, -.1794E+04, -.1576E+04,
.1E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
-.1419E+04, -.1173E+04, -.1017E+04,
0.0, 0.0, -.2011E+04, -.2011E+04, -.1677E+04,
-.13E+02, 0.0, 0.0, 0.0, 0.0, 0.0,
.681E+03, .491E+03, .597E+03, -.26E+02,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
.8E+02, .8E+02, 0.0, 0.0, 0.0, 0.0,
.8E+02, .8E+02, .8E+02, .8E+02, .8E+02,
.8E+02, .8E+02, .8E+02, .8E+02, .8E+02,
0.0, .8E+02, .8E+02, .8E+02, .8E+02,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, .8E+02,
.8E+02, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
.8E+02, .8E+02, .8E+02, .8E+02, 0.0,
.8E+02, .8E+02, .8E+02, .8E+02, .8E+02,
.16E+03, .16E+03, .16E+03, .16E+03,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
.8E+02, .8E+02, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
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```
      ***** F-16 LIGHT WEIGHT FIGHTER *****
       AL-2024-T62 SKINS, STIFFENERS, RIBS, AND SPARS
$INCN
IT1       = 0,
IT2       = 0,
IT3       = 0,
IT4       = 0,
EPS1      = 0.0,
EPS2      = 0.0,
EPS3      = 0.0,
EPS4      = 0.0,
KEY1      = 1,
KEY2      = 1,
KEY3      = 1,
KEY4      = 5,
KEY5      = 0,
KEY6      = 0,
KEY7      = 1,
KEY8      = 1,
KEY9      = 1,
KEY10     = 1,
KEY11     = 1,
$END
$MATIN
NMAT      = 1,
MATIO     = 4, 0, 0, 0, 0, 0,
FTEN      = .85,
$END
$LIF
CYMAX     = .8E+05,
FREQ      = .2E+01,
ASUBQ     = 0.500,
FLTFG     = 10000.0,
MSUBD     = 2,
ASUBD     = 11.25,
CRS       = .85E+20,
MSUBDL    = 0,
ASUBDL    = 0.0,
CRSL      = 0.0,
IOSPEC    = 2,
ICFROC    = 3,
$END
$FMCN
IFM       = 0, 0, 0,
$END
$GINPT
NSTAG = 10,
STAG  =    0.0, 21.64, 43.29, 64.93, 86.57, 108.21, 129.86,
        151.5,173.14,194.79, 10*0.0,
XLOWF =  91.60,  83.74,  75.88,  68.02,  60.15,  52.29,
         44.43,  36.56,  28.70,  20.84,  10*0.0,
ZLORF =  20*0.,
CX  = 43.10, 38.48, 34.87, 31.26, 27.64, 24.03, 20.42, 16.80, 13.19,
        9.58, 10*0.0,
      66.65, 61.11, 55.37, 49.64, 43.90, 38.16, 32.42, 26.68, 20.95,
      15.21, 10*0.0,
      91.60, 83.74, 75.88, 68.02, 60.15, 52.29, 44.43, 36.56, 28.70,
      20.84, 10*0.0,
     116.36,106.37, 96.38, 86.39, 76.41, 66.42, 56.43, 46.45, 36.46,
      26.47, 10*0.0,
     141.11,129.00,116.89,104.77, 92.66, 80.55, 68.44, 56.33, 44.21,
      32.10, 10*0.0,
     141.11,129.00,116.89,104.77, 92.66, 80.55, 68.44, 56.33, 44.21,
      32.10, 10*0.0,
     116.36,106.37, 96.38, 86.39, 76.41, 66.42, 56.43, 46.45, 36.46,
      26.47, 10*0.0,
      91.60, 83.74, 75.88, 68.02, 60.15, 52.29, 44.43, 36.56, 28.70,
      20.84, 10*0.0,
      66.65, 61.11, 55.37, 49.64, 43.90, 38.16, 32.42, 26.68, 20.95,
      15.21, 10*0.0,
      43.10, 38.48, 34.87, 31.26, 27.64, 24.03, 20.42, 16.80, 13.19,
       9.58, 210*0.0,
CZ  =   4.31,   3.94,   3.57,   3.20,   2.83,   2.46,   2.09,   1.72,   1.35,
        0.98,  10*0.0,
        4.85,   4.43,   4.01,   3.60,   3.18,   2.77,   2.35,   1.93,   1.52,
        1.10,  10*0.0,
        4.63,   4.20,   3.81,   3.41,   3.02,   2.62,   2.23,   1.83,   1.44,
        1.05,  10*0.0,
        3.64,   3.33,   3.02,   2.71,   2.39,   2.08,   1.77,   1.45,   1.14,
        0.83,  10*0.0,
        2.31,   2.11,   1.91,   1.72,   1.52,   1.32,   1.12,   0.92,   0.72,
        0.53,  10*0.0,
       -0.71,  -0.65,  -0.59,  -0.53,  -0.47,  -0.41,  -0.34,  -0.28,  -0.22,
       -0.16,  10*0.0,
       -1.64,  -1.50,  -1.36,  -1.22,  -1.08,  -0.94,  -0.80,  -0.66,  -0.51,
       -0.37,  10*0.0,
       -2.48,  -2.27,  -2.06,  -1.84,  -1.63,  -1.42,  -1.20,  -0.99,  -0.78,
       -0.56,  10*0.0,
       -2.91,  -2.66,  -2.41,  -2.16,  -1.91,  -1.66,  -1.41,  -1.16,  -0.91,
       -0.66,  10*0.0,
       -2.65,  -2.42,  -2.20,  -1.97,  -1.74,  -1.51,  -1.29,  -1.06,  -0.83,
       -0.60,  210*0.0,
GTRX  =  20*0.,
GTRZ  =  20*0.,
NODES = 10,
NSEB  = 3,
NLONG = 4,
ITEM = 1,2,3,4,5,6,7,8,9,10,10*0,
IW = 6*0,
IL = 1, 5, 6, 10, 6*0,
OL = 0., 0., 180., 180., 6*0.,
FASP = 10*20.,10*0.,
$END
```

```
$PARTS
ASPAN2 = 904.,
CX1 = 0.,
NRIBS = 45,
RIBSP = 20.,
$END
$LAK
NSGP     = 2,
NSGM     = 0,
NSGL     = 2,
$END
$LINKN
KMAX     = 4, 4,
NSE      = 1, 2, 3, 4, 16*0,
           6, 7, 8, 9, 16*0,
           360*0,
$END
$LINKN
KMAX     = 2, 2,
NSE      = 1, 5, 18*0,
           6, 10, 18*0,
           360*0,
$END
$SUBIN1
ITYPE    = 1, 1, 21, 21, 0,
IDSET    = 1, 1, 2, 2, 0,
IDMAT1   = 1, 1, 1, 1, 0,
IDMAT2   = 0, 0, 0, 0, 0,
FELEM    = .1E+01, .1E+01, 0.0, 0.0, 0.0,
T        = 1.000, 0.100, 18*0.0,
           1.000, 0.100, 18*0.0,
           20*0.0,
           20*0.0,
TMN      = 0.040, 0.040, 18*0.0,
           0.040, 0.040, 18*0.0,
           20*0.0,
           20*0.0,
B        = 5.000, 5.000, 18*0.0,
           1.000, 1.000, 18*0.0,
           20*0.0,
           20*0.0,
BMN      = 20*0.0,
           1.000, 1.000, 18*0.0,
           20*0.0,
           20*0.0,
BMX      = 20*0.0,
           2.000, 2.000, 18*0.0,
           20*0.0,
           20*0.0,
$END
$SUBIN1
ITYPE    = 2, 2, 0, 0, 0,
IDSET    = 1, 1, 0, 0, 0,
IDMAT1   = 1, 1, 0, 0, 0,
IDMAT2   = 5*0,
FELEM    = 0.0, 0.0, 0.0, 0.0, 0.0,
T        = 0.100, 19*0.0,
           0.100, 19*0.0,
           0.100, 19*0.0,
           20*0.0,
TMN      = 0.040, 19*0.0,
           0.040, 19*0.0,
           0.040, 19*0.0,
           20*0.0,
B        = 1.000, 19*0.0,
           1.000, 19*0.0,
           1.000, 19*0.0,
           20*0.0,
BMN      = 20*0.0,
           20*0.0,
           20*0.0,
           20*0.0,
BMX      = 1.000, 19*0.0,
           1.000, 19*0.0,
           1.000, 19*0.0,
           20*0.0,
$END
$SUBN2
IFT      = 3,
IDMTFR   = 1,
$END
9.0 G PULL UP    (16-62.? ) M=0.95, GW=21285
-3.0 G PUSH OVER (16-70.? ) M=1.20, GW=21289
4.25G R.P.O.     (16-80.?L) M=0.90, GW=32261
-1.0 G ROLL      (16-83.?R) M=?, GW=33000
-3.0 G PSPO      (16-86.? ) M=1.20, GW=21289
-1.0 G ROLL      (16-90.?L) M=1.20, GW=22177
1.0 G TAXI
1.0 G FLIGHT
1.0 G FLIGHT + 1.0 G GUST
1.0 G FLIGHT + 1.0 G MANEUVER
1.0 G LANDING IMPACT
MAXIMUM CABIN PRESSURE
```

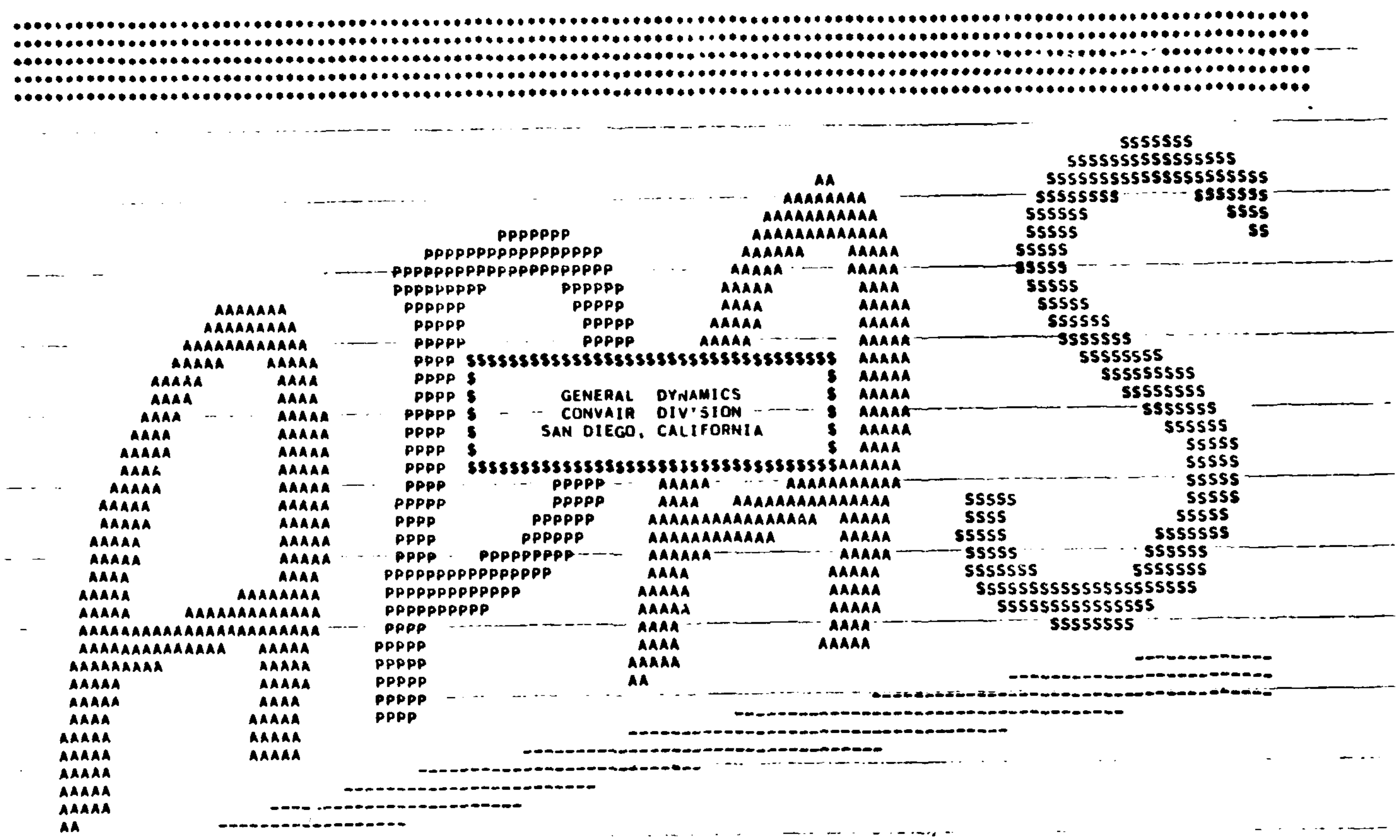
```
$LDLN
NCOND    = 6,
NSPEC    = 6,
FBUCK    = 0.400,
FULT     = 1.500,
NSTAY    = 11*17, 2,
PRES     = 12*0.0,
FLIN     = 12*154.79,
FLD      = 12*1.0,
FA       = 12*1.0,
FXS      = 12*1.0,
FZS      = 12*1.0,
FTOR     = 12*1000.0,
FXM      = 12*1000.0,
FZM      = 12*1.0,
FTEMP    = 12*1.0,
STA      = 0.000, 0.100, 0.162, 0.162, 0.200, 0.300, 0.400, 0.500,
           0.539, 0.539, 0.600, 0.700, 0.800, 0.823, 0.823, 0.900,
           1.000, 3*0.0,
           0.000, 0.100, 0.162, 0.162, 0.200, 0.300, 0.400, 0.500,
           0.539, 0.539, 0.600, 0.700, 0.800, 0.823, 0.823, 0.900,
           1.000, 3*0.0,
           0.000, 0.100, 0.162, 0.162, 0.200, 0.300, 0.400, 0.500,
           0.539, 0.539, 0.600, 0.700, 0.800, 0.823, 0.823, 0.900,
           1.000, 3*0.0,
           0.000, 0.100, 0.162, 0.162, 0.200, 0.300, 0.400, 0.500,
           0.539, 0.539, 0.600, 0.700, 0.800, 0.823, 0.823, 0.900,
           1.000, 3*0.0,
           0.000, 0.100, 0.162, 0.162, 0.200, 0.300, 0.400, 0.500,
           0.539, 0.539, 0.600, 0.700, 0.800, 0.823, 0.823, 0.900,
           1.000, 3*0.0,
           0.000, 0.100, 0.162, 0.162, 0.200, 0.300, 0.400, 0.500,
           0.539, 0.539, 0.600, 0.700, 0.800, 0.823, 0.823, 0.900,
           1.000, 3*0.0,
           0.000, 0.100, 0.162, 0.162, 0.200, 0.300, 0.400, 0.500,
           0.539, 0.539, 0.600, 0.700, 0.800, 0.823, 0.823, 0.900,
           1.000, 3*0.0,
           0.000, 0.100, 0.162, 0.162, 0.200, 0.300, 0.400, 0.500,
           0.539, 0.539, 0.600, 0.700, 0.800, 0.823, 0.823, 0.900,
           1.000, 3*0.0,
           0.000, 0.100, 0.162, 0.162, 0.200, 0.300, 0.400, 0.500,
           0.539, 0.539, 0.600, 0.700, 0.800, 0.823, 0.823, 0.900,
           1.000, 3*0.0,
           0.000, 0.100, 0.162, 0.162, 0.200, 0.300, 0.400, 0.500,
           0.539, 0.539, 0.600, 0.700, 0.800, 0.823, 0.823, 0.900,
           1.000, 3*0.0,
           0.000, 0.100, 0.162, 0.162, 0.200, 0.300, 0.400, 0.500,
           0.539, 0.539, 0.600, 0.700, 0.800, 0.823, 0.823, 0.900,
           1.000, 3*0.0,
           0.000, 1.000, 18*0.0,
AXL      = 240*0.0,
XSF      = 240*0.0,
ZSF      =  54045.,  47605.,  43464.,  44077.,  41951.,  35727.,
            29730.,  23557.,  21942.,  21853.,  18587.,  13264.,
             8226.,   7132.,   7211.,   4295.,    460.,  3*0.0,
           -23075., -21257., -19905., -20099., -19415., -17330.,
           -15076., -12641., -11626., -11746., -10247.,  -7705.,
            -5124.,  -4526.,  -4586.,  -2710.,   -530.,  3*0.0,
            18664.,  10707.,   5433.,  37581.,  30125.,  23077.,
            16516.,  10240.,   7715.,  15564.,  12444.,   7609.,
             4048.,   3796.,   3502.,   1374.,  -1255.,  3*0.0,
              920.,   5707.,   7548.,  -1323.,    295.,   4335.,
             7372.,  10274.,  11119.,  -1423.,   -162.,   1441.,
             1401.,   1217.,   1101.,   1182.,   1627.,  3*0.0,
           -16977., -16601., -14142., -16336., -16165., -17119.,
           -15756., -13295., -13110., -13253., -11991.,  -4466.,
            -7072.,  -6426.,  -5466.,  -4349.,  -1361.,  3*0.0,
            -6249.,  -4715., -10520., -12465., -11527., -11211.,
           -14345., -14774., -14647., -14562., -14205., -12719.,
           -10273.,  -9541., -10679.,  -6055.,  -3525.,  3*0.0,
            -7600.,  -7470.,  -7330.,  -7335.,  -7250.,  -6645.,
            -6330.,  -5560.,  -5300.,  -5250.,  -4795.,  -4220.,
            -2735.,  -2595.,  -2570.,  -1740.,   -545.,  3*0.0,
             6005.,   5310.,   4830.,   4895.,   4660.,   3470.,
             3310.,   2650.,   2340.,   2425.,   2065.,   1475.,
              915.,    790.,    610.,    475.,    105.,  3*0.0,
            12010.,  10620.,   9660.,   9790.,   9320.,   7940.,
             6620.,   5300.,   4760.,   4660.,   4130.,   2450.,
             1830.,   1560.,   1620.,    950.,    210.,  3*0.0,
            12010.,  10620.,   9660.,   9790.,   9320.,   7940.,
             6620.,   5300.,   4760.,   4660.,   4130.,   2450.,
             1830.,   1560.,   1620.,    950.,    210.,  3*0.0,
             6005.,   5310.,   4830.,   4895.,   4660.,   3470.,
             3310.,   2650.,   2340.,   2425.,   2065.,   1475.,
              915.,    790.,    610.,    475.,    105.,  3*0.0,
           20*0.0,
```

```
TORQ     =  -463.30,  -677.57,  -536.41,  -538.41,  -469.61,  [illegible],
             -230.70,  -152.36,  -135.22,  [illegible],  [illegible],  [illegible],
              -42.57,  [illegible],  -30.66,  [illegible],  [illegible],  3*0.0,
              216.11,  [illegible],  115.04,  118.0,  102.62,  [illegible],
               50.65,  [illegible],  33.67,  33.67,  [illegible],  33.70,
               16.76,  [illegible],  13.25,  7.71,  [illegible],  3*0.0,
             -2126.5,  -1953.6,  -1849.4,  [illegible],  -806.1,  [illegible],
              -466.6,  -370.6,  -345.3,  -136.7,  -87.0,  -41.3,
               -30.5,  -30.9,  -30.9,  -35.,  -47.1,  3*0.0,
              1156.3,  977.0,  893.,  709.,  646.3,  516.2,
               417.2,  345.6,  324.1,  143.,  84.5,  26.6,
                11.6,  11.6,  11.,  18.,  33.0,  3*0.0,
              -141.9,  [illegible],  -144.5,  -144.,  -137.1,  -112.4,
               -69.5,  -73.4,  -61.4,  -63.,  [illegible],  -32.5,
               -25.3,  -23.6,  -23.6,  -13.,  3.9,  3*0.0,
              -721.3,  -742.5,  [illegible],  -638.,  -577.7,  -436.3,
              -324.6,  -241.0,  -216.,  -216.,  -155.2,  [illegible],
              -151.0,  -152.5,  [illegible],  -50.1,  -38.1,  3*0.0,
               -56.8,  -59.5,  -57.8,  -57.,  -54.8,  -45.0,
               -35.6,  -26.2,  -25.4,  -25.4,  -21.1,  -13.0,
               -10.1,  -9.4,  -9.4,  [illegible],  -0.5,  3*0.0,
              -107.0,  -75.3,  -59.0,  -59.,  -52.2,  -36.7,
               -25.6,  -17.4,  -15.0,  -15.,  -11.5,  -7.3,
                -4.7,  -4.3,  -4.3,  [illegible],  -2.9,  3*0.0,
              -214.0,  -150.6,  -119.6,  -119.,  -104.4,  -73.4,
               -51.2,  -34.6,  -30.0,  -30.,  -23.0,  -14.6,
                -9.4,  -6.6,  [illegible],  -7.,  -5.8,  3*0.0,
              -214.0,  -150.6,  -119.6,  -119.,  -104.4,  -73.4,
               -51.2,  -34.0,  -30.0,  -30.,  -23.0,  -14.6,
                -9.4,  -6.6,  [illegible],  -7.,  -5.8,  3*0.0,
              -107.0,  -75.3,  [illegible],  -59.,  -52.2,  -36.7,
               -25.6,  -17.4,  -15.0,  -15.,  -11.5,  -7.3,
                -4.7,  -4.3,  -4.3,  [illegible],  -2.4,  3*0.0,
             20*0.0,
XPOM     =   3179.7,  2531.6,  2179.3,  2179.,  1471.6,  1473.2,
              1155.0,  724.6,  614.3,  614.3,  457.5,  255.7,
               113.2,  56.0,  56.0,  40.,  5.7,  3*0.0,
             -1582.1,  -1247.5,  -1135.4,  -1135.,  -1036.3,  -801.4,
              -593.9,  -416.5,  -357.,  -357.,  -270.2,  -154.9,
               -72.3,  -57.7,  -57.7,  -22.,  -3.0,  3*0.0,
              1439.3,  1265.1,  1212.4,  1292.,  1143.3,  [illegible],
               565.6,  [illegible],  364.2,  329.,  222.7,  37.6,
                25.1,  14.3,  14.3,  -8.,  -8.7,  3*0.0,
              [illegible],  [illegible],  527.5,  441.,  436.9,  403.0,
               320.6,  215.1,  162.,  65.,  69.6,  [illegible],
                41.5,  37.3,  37.3,  25.,  12.1,  3*0.0,
             -1643.7,  -1491.6,  -1256.0,  -1256.,  [illegible],  [illegible],
              -727.1,  -536.5,  -469.,  -469.,  -363.4,  -229.7,
              -121.5,  -101.1,  -101.1,  -47.,  -11.0,  3*0.0,
             -1966.3,  -1363.9,  -1262.7,  -1282.,  -1226.9,  -1063.9,
              -862.3,  -691.4,  -617.7,  -617.7,  -502.3,  -327.0,
              -176.7,  -196.6,  -156.2,  -85.,  -27.1,  3*0.0,
              -657.4,  -550.7,  -502.4,  -502.,  -466.4,  [illegible],
              -290.8,  -214.6,  -167.7,  -167.,  -147.6,  [illegible],
               -40.6,  -40.4,  -40.4,  -19.,  -4.4,  3*0.0,
               357.3,  [illegible],  242.1,  242.,  219.1,  163.7,
               117.7,  80.5,  68.,  68.,  50.8,  [illegible],
                13.2,  10.7,  10.7,  4.,  1.0,  3*0.0,
               706.6,  562.6,  484.2,  484.,  436.2,  327.4,
               235.4,  151.0,  136.,  136.,  101.6,  [illegible],
                26.4,  21.4,  21.4,  8.,  [illegible],  3*0.0,
               706.6,  562.6,  464.2,  484.,  438.2,  327.4,
               235.4,  151.0,  156.6,  136.,  101.6,  [illegible],
                26.4,  21.4,  21.4,  8.,  [illegible],  3*0.0,
               353.3,  [illegible],  242.1,  242.1,  219.1,  163.7,
               117.7,  [illegible],  68.3,  68.,  50.8,  [illegible],
                13.2,  10.7,  10.7,  4.4,  1.0,  3*0.0,
             20*0.0,
ZPOM     =  240*0.0,
TEMP     =  17*80.0,  3*0.0,
             17*80.0,  3*0.0,
             17*80.0,  3*0.0,
             17*80.0,  3*0.0,
             17*80.0,  3*0.0,
             17*80.0,  3*0.0,
             17*80.0,  3*0.0,
             17*80.0,  3*0.0,
             17*80.0,  3*0.0,
             17*80.0,  3*0.0,
             17*80.0,  3*0.0,
             17*80.0,  3*0.0,
             2*80.0,  16*0.0,
$END
```

4.2 RESULTS OF OPERATIONS

4.2.1 DESCRIPTION OF RESULTS. The results of the APAS analysis are provided as printed output and also stored on files to be available for later use by parts prediction and cost routines.

4.2.2 OUTPUT FORMAT AND CONTENT. A typical print-out is illustrated in Figure 4-46. The test case evaluates an all-metal wing with 2024-762 aluminum skins, riveted 7075-T6 aluminum "J" stiffeners, and 6A1-4V titanium ribs and spare. The example includes fatigue, flow growth, and residual strength analysis.



VERSION III.0
GENERATION DATE 01/22/78
EXECUTION DATE 06/19/81
TIME 10.04.56.

```
                              $$$$ INPUT DATA READ BY APAS $$$$

DATA READ BY SUBROUTINE INCON
    TITLE IS          ***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
                      AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS
    IT(I) =    5, 20,   5,   5
    EPS(I) =    .001000,    .010000,    .001000,    .001000
    KEY(I) =    1,   1,   1, 30,   0,   0,   1,   1,   1,   1,   1

DATA READ BY SUBROUTINE MATIN
    NMAT =  3, MATID(1) =  4, MATID(2) =  6, MATID(3) =  8, MATID(4) =  0, MATID(5) =  0, MATID(6) =  0,
    TEN(1) = 1.0000      TEN(2) = 1.0000      TEN(3) = 1.0000

DATA READ BY SUBROUTINE LIFE
    FATIGUE DESIGN CRITERIA
    FATIGUE DESIGN LIFE (FLIGHTS) =     80000.      FREQ = 2.000

    FLAW GROWTH CRITERIA
    INITIAL FLAW SIZE (A) = 1.000      INSPECTION INTERVAL (FLIGHTS) =     20000.

    DAMAGE TOLLERANCE CRITERIA
    MSUBD  =  1      ASUBD  = 7.500      CRS  =  .850

    SPECTRUM SPECIFICATION DATA
    IDSPEC =  1      IDPROC =  0

DATA READ BY SUBROUTINE FATTIN

DATA READ BY SUBROUTINE FMDIN
    MATID =  4 ,IFM =  0        ,AC =    .4936E-20 ,AM =    .600       ,AN =  3.680  ,AQ =  .300
               ,AKC =  60000. ,AKIC =   30000.    ,THRESH =   2500.  ,SHUT =  3.000 ,RCUT =  .8000 ,RCUTN = -.5000
    MATID =  6 ,IFM =  0        ,AC =    .1247E-18 ,AM =    .600       ,AN =  3.430  ,AQ =  .300
               ,AKC =  52000. ,AKIC =   26000.    ,THRESH =   2500.  ,SHUT =  3.000 ,RCUT =  .8000 ,RCUTN = -.5000
    MATID =  8 ,IFM =  0        ,AC =    .1107E-22 ,AM =    .500       ,AN =  4.070  ,AQ =  .300
               ,AKC = 140000. ,AKIC =   70000.    ,THRESH =   4500.  ,SHUT =  3.500 ,RCUT =  .8500 ,RCUTN = -.5000

DATA READ BY SUBROUTINE GINPT1
    NODES = 10      NWEB =  0      NLONG =  4      NSTAG = 10
            STAG        FRSP       XLDRF       ZLDRF       GTRX       GTRZ
            0.00        20.00      160.59      0.00        0.00       0.00

      ITEM     GX         GZ       ITEM      GX         GZ       ITEM      GX        GZ
        1      64.23      35.59      2       112.41     48.86      3       160.59    47.45
        4     208.76      46.15      5       256.94     35.59      6       256.94   -17.79
        7     208.76     -19.07      8       160.59    -21.50      9       112.41   -22.24
       10      64.23     -22.24
            STAG        FRSP       XLDRF       ZLDRF       GTRX       GTRZ
            112.40      20.00      144.05      0.00        0.00       0.00

      ITEM     GX         GZ       ITEM      GX         GZ       ITEM      GX        GZ
```

ITEM	GX	GZ	ITEM	GX	GZ	ITEM	GX	GZ
1	57.62	30.95	2	100.84	39.01	3	144.05	41.27
4	187.27	40.14	5	230.48	30.95	6	230.48	-15.48
7	187.27	-16.59	8	144.05	-18.70	9	100.84	-19.35
10	57.62	-19.35						

STAG	FRSP	XLDRF	ZLDRF	GTRX	GTRZ
224.80	20.00	127.51	0.00	0.00	0.00

ITEM	GX	GZ	ITEM	GX	GZ	ITEM	GX	GZ
1	51.01	26.32	2	89.26	33.17	3	127.51	35.09
4	165.77	34.13	5	204.02	26.32	6	204.02	-13.16
7	165.77	-14.11	8	127.51	-15.90	9	89.26	-16.45
10	51.01	-16.45						

STAG	FRSP	XLDRF	ZLDRF	GTRX	GTRZ
337.21	20.00	110.98	0.00	0.00	0.00

ITEM	GX	GZ	ITEM	GX	GZ	ITEM	GX	GZ
1	44.39	21.69	2	77.68	27.33	3	110.98	28.92
4	144.28	28.13	5	177.56	21.69	6	177.56	-10.84
7	144.27	-11.62	8.	110.98	-13.18	9	77.68	-13.55
10	44.39	-13.55						

STAG	FRSP	XLDRF	ZLDRF	GTRX	GTRZ
449.81	20.00	94.44	0.00	0.00	0.00

ITEM	GX	GZ	ITEM	GX	GZ	ITEM	GX	GZ
1	37.78	17.05	2	66.11	21.49	3	94.44	22.74
4	122.77	22.12	5	151.06	17.05	6	151.06	-8.53
7	122.77	-9.14	8	94.44	-10.30	9	66.11	-10.66
10	37.18	-10.66						

STAG	FRSP	XLDRF	ZLDRF	GTRX	GTRZ
584.45	20.00	83.42	0.00	0.00	0.00

ITEM	GX	GZ	ITEM	GX	GZ	ITEM	GX	GZ
1	33.37	14.66	2	58.40	18.48	3	83.43	19.55
4	108.45	19.01	5	133.48	14.66	6	133.48	-7.33
7	108.45	-7.86	8	83.43	-8.86	9	58.40	-9.16
10	33.37	-9.16						

STAG	FRSP	XLDRF	ZLDRF	GTRX	GTRZ
719.29	20.00	72.41	0.00	0.00	0.00

ITEM	GX	GZ	ITEM	GX	GZ	ITEM	GX	GZ
1	28.98	12.27	2	50.68	15.47	3	72.41	16.37
4	94.13	15.92	5	115.86	12.27	6	115.86	-6.14
7	94.13	-6.58	8	72.41	-7.42	9	50.69	-7.67
10	28.98	-7.67						

STAG	FRSP	XLDRF	ZLDRF	GTRX	GTRZ
854.13	20.00	61.39	0.00	0.00	0.00

ITEM	GX	GZ	ITEM	GX	GZ	ITEM	GX	GZ
1	24.56	9.88	2	42.98	12.46	3	61.39	13.18
4	79.81	12.82	5	98.23	9.88	6	98.23	-4.94
7	79.81	-5.30	8	61.39	-5.98	9	42.98	-6.18
10	24.56	-6.18						

STAG	FRSP	XLDRF	ZLDRF	GTRX	GTRZ
988.97	20.00	50.38	0.00	0.00	0.00

```
  ITEM      GX        GZ      ITEM      GX        GZ      ITEM      GX        GZ
     1    20.15      7.49        2    35.26      9.45        3    50.38      9.99
     4    65.49      9.72        5    80.60      7.49        6    80.60     -3.75
     7    65.49     -4.02        8    50.38     -4.53        9    35.26     -4.68
    10    20.15     -4.68
       STAG       FRSP     XLDRF      ZLDRF      GTRX       GTRZ
     1123.80     20.00     39.36       0.00       0.00       0.00

  ITEM      GX        GZ      ITEM      GX        GZ      ITEM      GX        GZ
     1    15.75      5.10        2    27.55      8.43        3    39.36      6.81
     4    51.17      8.62        5    62.98      5.10        6    62.98     -2.55
     7    51.17     -2.74        8    39.36     -3.08        9    27.55     -3.19
    10    16.75     -3.19
 LONGERON ( 1) NODE = (  1) DIRECTION = (   0.00)
 LONGERON ( 2) NODE = (  5) DIRECTION = (   0.00)
 LONGERON ( 3) NODE = (  6) DIRECTION = ( 180.00)
 LONGERON ( 4) NODE = ( 10) DIRECTION = ( 180.00)

DATA READ BY SUBROUTINE LINK
 NSGP = ( 2), NSGW = ( 0), NSGL = ( 2)
 PANEL SYMMETRY GROUPS
 GROUP NO.( 1), ( 4) ELEMENTS FOLLOW  1, 2, 3, 4,
 GROUP NO.( 2), ( 4) ELEMENTS FOLLOW  6, 7, 8, 9,
 LONGERON SYMMETRY GROUPS
 GROUP NO.( 1), ( 2) ELEMENTS FOLLOW  1, 5,
 GROUP NO.( 2), ( 2) ELEMENTS FOLLOW  6,10,
 PANEL DETAIL GEOMETRY FOLLOWS

DATA READ BY SUBROUTINE SUBIN1
 INFORMATION FOR SYMMETRY GROUP( 1), CONTAINING ELEMENTS  1, 2, 3, 4,
 CONSTRUCTION TYPE  5,      SET ID =   1,     SKIN MATERIAL NO =  1,     STIFFENER MAT. NO =  2,     PANEL WIDTH FACTOR =      1.
     T(I) = (     .1000,     .1000,     .1000,     .1000)
  TMIN(I) = (     .0800,     .0400,     .0400,     .0400)
     B(I) = (    6.0000,    1.5000,     .7500,    2.0000)
  BMIN(I) = (    0.0000,    0.0000,     .1000,    0.0000)
  BMAX(I) = (    6.0000,    1.5000,    1.0000,    2.0000)
 INFORMATION FOR SYMMETRY GROUP( 2), CONTAINING ELEMENTS  6, 7, 8, 9,
 CONSTRUCTION TYPE  5,      SET ID =   2,     SKIN MATERIAL NO =  1,     STIFFENER MAT. NO =  2,     PANEL WIDTH FACTOR =      1.
     T(I) = (     .1000,     .1000,     .1000,     .1000)
  TMIN(I) = (     .0800,     .0400,     .0400,     .0400)
     B(I) = (    7.5000,    1.5000,     .7500,    2.0000)
  BMIN(I) = (    0.0000,    0.0000,     .0100,    0.0000)
  BMAX(I) = (    7.5000,    1.5000,    1.0000,    2.0000)
 INFORMATION FOR SYMMETRY GROUP( 3), CONTAINING ELEMENTS  5,
 CONSTRUCTION TYPE 21,      SET ID =   3,     NO OF MATERIAL =  3,     PANEL WIDTH FACTOR =      1.000
     T(I) = (     .1000,     .1000,    0.0000,    0.0000)
  TMIN(I) = (     .0400,     .0400,    0.0000,    0.0000)
     B(I) = (    5.5000,    1.5000,    0.0000,    0.0000)
  BMIN(I) = (    0.0000,     .5000,    0.0000,    0.0000)
  BMAX(I) = (    5.5000,    2.0000,    0.0000,    0.0000)
 INFORMATION FOR SYMMETRY GROUP( 4), CONTAINING ELEMENTS 10,
 CONSTRUCTION TYPE 21,      SET ID =   3,     NO OF MATERIAL =  3,     PANEL WIDTH FACTOR =      1.000
 LONGERON DETAIL GEOMETRY FOLLOWS

DATA READ BY SUBROUTINE SUBIN1
 INFORMATION FOR SYMMETRY GROUP( 1), CONTAINING ELEMENTS  1, 2,
 CONSTRUCTION TYPE  2,      SET ID =   1,     NO OF MATERIAL =  3
     T(I) = (     .1000,     .1000,     .1000,    0.0000)
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TMIN(I) = (     .0400,      .0400,      .0400,     0.0000)
   B(I) = (    1.5000,     1.5000,     1.5000,     0.0000)
BMIN(I) = (    0.0000,     0.0000,     0.0000,     0.0000)
BMAX(I) = (    2.5000,     2.5000,     2.5000,     0.0000)
INFORMATION FOR SYMMETRY GROUP( 2), CONTAINING ELEMENTS  3, 4,
CONSTRUCTION TYPE  2,      SET ID =   1,      NO OF MATERIAL =  3
```

DATA READ BY SUBROUTINE SUBIN2
INFORMATION FOR AIRFOIL RIBS
RIB CONSTRUCTION TYPE 3, NO OF MATERIAL = 1

DATA READ BY SUBROUTINE LDLN1

DATA READ FOR 4 DESIGN LOADING CONDITIONS WITH AN ULTIMATE FACTOR OF 1.50
AND 6 LOADING CONDITIONS FOR SPECTRUM DEFINITION, SKIN BUCKLING FACTOR IS .40

COND NO. 1 2.5G POSITIVE MANEUVER S-4 WING DEFINED AT 10 STATIONS PRES = 0.00 PSI
FLIN = 1123.900, FLD = .667, FA = 1.000, FXS = 1.000, FZS = 1.000
FTOR = 1000.000, FXM = 1000.000, FZM = 1000.000, FTEMP = 1.000

FACTORED INPUT LOADS FOLLOW

STATION	AXIAL	XSHEAR	ZSHEAR	TORSION	XMOMENT	ZMOMENT	TEMP
0.0	-.152E+05	-.767E+02	.763E+05	.218E+06	.324E+08	-.141E+07	.800E+02
111.4	-.152E+05	-.767E+02	.763E+05	.218E+06	.324E+08	-.141E+07	.800E+02
220.7	-.123E+05	-.202E+04	.782E+05	-.101E+07	.271E+08	-.135E+07	.800E+02
366.5	-.977E+04	-.163E+04	.621E+05	-.201E+07	.205E+08	-.118E+07	.800E+02
367.0	-.985E+04	-.730E+03	.631E+05	.215E+06	.206E+08	-.117E+07	.800E+02
436.4	-.881E+04	-.819E+03	.578E+05	.632E+05	.178E+08	-.113E+07	.800E+02
436.5	-.834E+04	-.261E+04	.691E+05	.968E+06	.173E+08	-.101E+07	.800E+02
815.1	-.285E+04	-.103E+04	.247E+05	-.290E+06	.428E+07	-.409E+06	.800E+02
815.2	-.239E+04	-.283E+04	.360E+05	.322E+06	.391E+07	-.325E+06	.800E+02
1123.9	-.402E+03	-.485E+03	.614E+04	.326E+05	.157E+06	-.136E+05	.800E+02

COND NO. 2 -1.0G NEGATIVE MANEUVER S-4 WING DEFINED AT 10 STATIONS PRES = 0.00 PSI
FLIN = 1123.900, FLD = .667, FA = 1.000, FXS = 1.000, FZS = 1.000
FTOR = 1000.000, FXM = 1000.000, FZM = 1000.000, FTEMP = 1.000

FACTORED INPUT LOADS FOLLOW

STATION	AXIAL	XSHEAR	ZSHEAR	TORSION	XMOMENT	ZMOMENT	TEMP
0.0	.268E+04	-.640E+04	-.238E+05	-.189E+07	-.133E+08	-.202E+07	.800E+02
111.4	.268E+04	-.640E+04	-.238E+05	-.189E+07	-.133E+08	-.202E+07	.800E+02
220.7	.109E+04	-.642E+04	-.276E+05	-.198E+07	-.112E+08	-.152E+07	.800E+02
366.5	-.687E+02	-.680E+04	-.251E+05	-.144E+07	-.880E+07	-.848E+06	.800E+02
367.0	-.840E+03	-.674E+04	-.255E+05	-.238E+07	-.859E+07	-.850E+06	.800E+02
436.4	-.135E+04	-.687E+04	-.247E+05	-.207E+07	-.763E+07	-.536E+06	.800E+02
436.5	.127E+04	-.201E+04	-.293E+05	-.226E+07	-.755E+07	-.540E+06	.800E+02
815.1	-.140E+04	-.333E+04	-.145E+05	-.593E+06	-.192E+07	.197E+06	.800E+02
815.2	.120E+04	.152E+04	-.191E+05	-.661E+06	-.189E+07	.183E+06	.800E+02
1123.9	.233E+03	.302E+03	-.380E+04	-.107E+06	-.409E+05	.880E+04	.800E+02

COND NO. 3 2.0G TAXI S-4 WING DEFINED AT 10 STATIONS PRES = 0.00 PSI
FLIN = 1123.900, FLD = .667, FA = 1.000, FXS = 1.000, FZS = 1.000
FTOR = 1000.000, FXM = 1000.000, FZM = 1000.000, FTEMP = 1.000

FACTORED INPUT LOADS FOLLOW

STATION	AXIAL	XSHEAR	ZSHEAR	TORSION	XMOMENT	ZMOMENT	TEMP
0.0	-.980E+04	.943E+04	-.107E+06	-.191E+05	-.249E+08	.220E+07	.800E+02
111.4	-.980E+04	.943E+04	-.107E+06	-.191E+05	-.249E+08	.220E+07	.800E+02
220.7	-.742E+04	.714E+04	-.806E+05	-.251E+06	-.178E+08	.155E+07	.800E+02
366.5	-.559E+04	.538E+04	-.608E+05	-.461E+06	-.107E+08	.905E+06	.800E+02
367.0	-.492E+04	.586E+04	-.599E+05	-.157E+07	-.106E+08	.908E+06	.800E+02
436.4	-.442E+04	.527E+04	-.538E+05	-.153E+07	-.798E+07	.655E+06	.800E+02
436.5	-.368E+04	.438E+04	-.448E+05	-.512E+06	-.857E+07	.796E+06	.800E+02
815.1	-.141E+04	.167E+04	-.171E+05	-.741E+06	-.269E+06	-.344E+05	.800E+02
815.2	-.660E+03	.787E+03	-.806E+04	-.391E+05	-.761E+06	.776E+05	.800E+02
1123.9	-.534E+02	.667E+02	-.660E+03	.320E+04	-.183E+05	.207E+04	.800E+02

COND NO. 4 1.0G FLIGHT S-4 WING DEFINED AT 10 STATIONS PRES = 0.00 PSI
FLIN = 1123.900, FLD = .667, FA = 1.000, FXS = 1.000, FZS = 1.000
FTOR = 1000.000, FXM = 1000.000, FZM = 1000.000, FTEMP = 1.000

FACTORED INPUT LOADS FOLLOW

STATION	AXIAL	XSHEAR	ZSHEAR	TORSION	XMOMENT	ZMOMENT	TEMP
0.0	-.486E+04	-.150E+04	.217E+05	-.231E+07	.577E+07	-.120E+07	.800E+02
111.4	-.486E+04	-.150E+04	.217E+05	-.231E+07	.577E+07	-.120E+07	.800E+02
220.7	-.434E+04	-.251E+04	.187E+05	-.269E+07	.441E+07	-.105E+07	.800E+02
366.5	-.414E+04	-.331E+04	.105E+05	-.263E+07	.288E+07	-.764E+06	.800E+02
367.0	-.445E+04	-.287E+04	.108E+05	-.230E+07	.315E+07	-.763E+06	.800E+02
436.4	-.438E+04	-.321E+04	.807E+04	-.213E+07	.260E+07	-.619E+06	.800E+02
436.5	-.232E+04	-.834E+03	.111E+05	-.154E+07	.223E+07	-.523E+06	.800E+02
815.1	-.208E+04	-.222E+04	-.143E+04	-.862E+06	.609E+06	-.594E+05	.800E+02
815.2	-.200E+02	.153E+03	.159E+04	-.351E+06	.274E+06	.120E+05	.800E+02
1123.9	-.133E+02	.667E+01	-.253E+03	-.614E+05	.320E+05	-.667E+03	.800E+02

COND NO. 5 1.0G TAXI S-4 WING DEFINED AT 10 STATIONS PRES = 0.00 PSI
FLIN = 1123.900, FLD = .667, FA = 1.000, FXS = 1.000, FZS = 1.000
FTOR = 1000.000, FXM = 1000.000, FZM = 1000.000, FTEMP = 1.000

FACTORED INPUT LOADS FOLLOW

STATION	AXIAL	XSHEAR	ZSHEAR	TORSION	XMOMENT	ZMOMENT	TEMP
0.0	-.490E+04	.472E+04	-.533E+05	-.934E+04	-.124E+08	.110E+07	.800E+02
111.4	-.490E+04	.472E+04	-.533E+05	-.934E+04	-.124E+08	.110E+07	.800E+02
220.7	-.371E+04	.357E+04	-.403E+05	-.125E+06	-.890E+07	.776E+06	.800E+02
366.5	-.279E+04	.269E+04	-.304E+05	-.230E+06	-.535E+07	.452E+06	.800E+02
367.0	-.246E+04	.293E+04	-.300E+05	-.785E+06	-.530E+07	.454E+06	.800E+02
436.4	-.221E+04	.263E+04	-.269E+05	-.763E+06	-.399E+07	.327E+06	.800E+02
436.5	-.184E+04	.219E+04	-.224E+05	-.256E+06	-.429E+07	.398E+06	.800E+02
815.1	-.704E+03	.837E+03	-.857E+04	-.370E+06	-.135E+06	-.173E+05	.800E+02
815.2	-.330E+03	.394E+03	-.403E+04	.193E+05	-.380E+06	.387E+05	.800E+02
1123.9	-.267E+02	.334E+02	-.330E+03	.133E+04	-.934E+04	.133E+04	.800E+02

COND NO. 6 1.0G FLIGHT S-4 WING DEFINED AT 10 STATIONS PRES = 0.00 PSI
FLIN = 1123.900, FLD = .667, FA = 1.000, FXS = 1.000, FZS = 1.000
FTOR = 1000.000, FXM = 1000.000, FZM = 1000.000, FTEMP = 1.000

FACTORED INPUT LOADS FOLLOW

STATION	AXIAL	XSHEAR	ZSHEAR	TORSION	XMOMENT	ZMOMENT	TEMP
0.0	-.486E+04	-.150E+04	.217E+05	-.231E+07	.577E+07	-.120E+07	.800E+02
111.4	-.486E+04	-.150E+04	.217E+05	-.231E+07	.577E+07	-.120E+07	.800E+02

220.7	-.434E+04	-.251E+04	.187E+05	-.269E+07	.441E+07	-.105E+07	.800E+02
366.5	-.414E+04	-.331E+04	.105E+05	-.263E+07	.288E+07	-.764E+06	.800E+02
367.0	-.445E+04	-.287E+04	.108E+05	-.230E+07	.315E+07	-.763E+06	.800E+02
436.4	-.438E+04	-.321E+04	.807E+04	-.213E+07	.260E+07	-.619E+06	.800E+02
436.5	-.232E+04	-.834E+03	.111E+05	-.154E+07	.223E+07	-.523E+06	.800E+02
815.1	-.208E+04	-.222E+04	-.143E+04	-.862E+06	.609E+06	-.594E+05	.800E+02
815.2	-.200E+02	.153E+03	.159E+04	-.351E+06	.274E+06	.120E+05	.800E+02
1123.9	-.133E+02	.667E+01	-.253E+03	-.614E+05	.320E+05	.667E+03	.800E+02

COND NO. 7 1.0G FLIGHT +1.0G GUST S-4 WING DEFINED AT 10 STATIONS PRES = 0.00 PSI
FLIN = 1123.900, FLD = .667, FA = 1.000, FXS = 1.000, FZS = 1.000
FTOR = 1000.000, FXM = 1000.000, FZM = 1000.000, FTEMP = 1.000

FACTORED INPUT LOADS FOLLOW

STATION	AXIAL	XSHEAR	ZSHEAR	TORSION	XMOMENT	ZMOMENT	TEMP
0.0	-.938E+04	-.219E+04	.392E+05	-.205E+07	.138E+08	-.153E+07	.800E+02
111.4	-.938E+04	-.219E+04	.392E+05	-.205E+07	.138E+08	-.153E+07	.800E+02
220.7	-.800E+04	-.361E+04	.378E+05	-.254E+07	.111E+08	-.133E+07	.800E+02
366.5	-.694E+04	-.400E+04	.263E+05	-.267E+07	.790E+07	-.948E+06	.800E+02
367.0	-.729E+04	-.331E+04	.268E+05	-.179E+07	.813E+07	-.946E+06	.800E+02
436.4	-.687E+04	-.356E+04	.227E+05	-.168E+07	.691E+07	-.782E+06	.800E+02
436.5	-.461E+04	-.157E+04	.288E+05	-.101E+07	.652E+07	-.678E+06	.800E+02
815.1	-.271E+04	-.228E+04	.497E+04	-.734E+06	.160E+07	-.994E+05	.800E+02
815.2	-.446E+03	-.285E+03	.111E+05	-.219E+06	.128E+07	-.293E+05	.800E+02
1123.9	-.580E+02	-.313E+02	.137E+04	-.420E+05	.667E+05	-.667E+03	.800E+02

COND NO. 8 1.0G FLIGHT PLUS 1.0G MAN. S-4 WING DEFINED AT 10 STATIONS PRES = 0.00 PSI
FLIN = 1123.900, FLD = .667, FA = 1.000, FXS = 1.000, FZS = 1.000
FTOR = 1000.000, FXM = 1000.000, FZM = 1000.000, FTEMP = .500

FACTORED INPUT LOADS FOLLOW

STATION	AXIAL	XSHEAR	ZSHEAR	TORSION	XMOMENT	ZMOMENT	TEMP
0.0	-.118E+05	-.551E+03	.581E+05	-.623E+06	.235E+08	-.134E+07	.800E+02
111.4	-.118E+05	-.551E+03	.581E+05	-.623E+06	.235E+08	-.134E+07	.800E+02
220.7	-.968E+04	-.219E+04	.584E+05	-.157E+07	.196E+08	-.125E+07	.800E+02
366.5	-.789E+04	-.219E+04	.449E+05	-.222E+07	.146E+08	-.104E+07	.800E+02
367.0	-.805E+04	-.144E+04	.457E+05	-.622E+06	.148E+08	-.104E+07	.800E+02
436.4	-.733E+04	-.161E+04	.412E+05	-.668E+06	.128E+08	-.959E+06	.800E+02
436.5	-.634E+04	-.202E+04	.498E+05	.131E+06	.123E+08	-.850E+06	.800E+02
815.1	-.259E+04	-.143E+04	.160E+05	-.481E+06	.306E+07	-.[illegible]93E+06	.800E+02
815.2	-.160E+04	-.183E+04	.246E+05	.980E+05	.270E+07	-.213E+06	.800E+02
1123.9	-.273E+03	-.321E+03	.401E+04	.133E+04	.115E+08	-.867E+04	.800E+02

COND NO. 9 1.0G LANDING IMPACT S-4 WING DEFINED AT 10 STATIONS PRES = 0.00 PSI
FLIN = 1123.900, FLD = .667, FA = 1.000, FXS = 1.000, FZS = 1.000
FTOR = 1000.000, FXM = 1000.000, FZM = 1000.000, FTEMP = 1.000

FACTORED INPUT LOADS FOLLOW

STATION	AXIAL	XSHEAR	ZSHEAR	TORSION	XMOMENT	ZMOMENT	TEMP
0.0	-.490E+04	.472E+04	-.533E+05	-.934E+04	-.124E+08	.110E+07	.800E+02
111.4	-.490E+04	.472E+04	-.533E+05	-.934E+04	-.124E+08	.110E+07	.800E+02
220.7	-.371E+04	.357E+04	-.403E+05	-.125E+06	-.890E+07	.776E+06	.800E+02
366.5	-.279E+04	.269E+04	-.304E+05	-.230E+06	-.535E+07	.452E+06	.800E+02
367.0	-.246E+04	.293E+04	-.300E+05	-.785E+06	-.530E+07	.454E+06	.800E+02
436.4	-.221E+04	.263E+04	-.269E+05	-.763E+06	-.399E+07	.327E+06	.800E+02
436.5	-.184E+04	.219E+04	-.224E+05	-.256E+06	-.429E+07	.398E+06	.800E+02

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 815.1 -.704E+03  .837E+03 -.857E+04 -.370E+06 -.135E+08 -.173E+05  .800E+02
 815.2 -.330E+03  .394E+03 -.403E+04  .193E+05 -.380E+08  .387E+05  .800E+02
1123.9 -.267E+02  .334E+02 -.330E+03  .133E+04 -.934E+04  .133E+04  .800E+02

COND NO. 10     MAXIMUM CABIN PRESSURE S-4 WING          DEFINED AT  2 STATIONS     PRES =   0.00 PSI
FLIN =  1123.900, FLD =       .667, FA =     1.000, FXS =     1.000, FZS =     1.000
FTOR =  1000.000, FXM =  1000.000, FZM =  1000.000, FTEMP =     1.000

FACTORED INPUT LOADS FOLLOW

   STATION     AXIAL    XSHEAR    ZSHEAR   TORSION   XMOMENT   ZMOMENT      TEMP

      0.0 0.          0.        0.        0.        0.        0.         .800E+02
   1123.9 0.          0.        0.        0.        0.        0.         .800E+02

****************************************************************************************************
                                  ALL INPUT DATA HAS BEEN SUCCESSFULLY READ
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***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 0.00

SECTION NODAL GEOMETRY

NODE	X	Z	NODE	X	Z	NODE	X	Z
1	64.23	35.59	2	112.41	48.86	3	160.59	47.45
4	208.78	46.15	5	256.94	35.59	6	256.94	-17.79
7	208.76	-19.07	8	160.59	-21.50	9	112.41	-22.24
10	64.23	-22.24						

SECTION PROPERTIES

CENTROID		LOAD REF.		SPACING	TAPER
XCG	ZCG	XLR	ZLR	L	RATIO
160.47	10.86	160.59	0.00	20.00	0.00

EA	EIXX	EIZZ	EIXZ	GJ
.538227E+09	.613353E+12	.174441E+13	.133811E+11	.501934E+12

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 0.00 INPUT LOADS

COND NO.	DESCRIPTION
1	2.5G POSITIVE MANEUVER S-4 WING
2	-1.0G NEGATIVE MANEUVER S-4 WING
3	2.0G TAXI S-4 WING
4	1.0G FLIGHT S-4 WING
5	1.0G TAXI S-4 WING
6	1.0G FLIGHT S-4 WING
7	1.0G FLIGHT +1.0G GUST S-4 WING
8	1.0G FLIGHT PLUS 1.0G MAN. S-4 WING
9	1.0G LANDING IMPACT S-4 WING
10	MAXIMUM CABIN PRESSURE S-4 WING

COND NO.	TEMP (F)	XSHEAR PX (LB)	AXIAL PY (LB)	ZSHEAR PZ (LB)	XMOMENT MX (IN-LB)	TORSION MY (IN-LB)	ZMOMENT MZ (IN-LB)
1	80.	-.767050E+02	-.152476E+05	.763048E+05	.324229E+08	.217842E+08	-.141337E+07
2	80.	-.639653E+04	.268067E+04	-.237519E+05	-.132533E+08	-.189361E+07	-.201701E+07
3	80.	.943138E+04	-.980490E+04	-.106520E+06	-.248858E+08	-.190762E+05	.220177E+07
4	80.	-.150075E+04	-.465576E+04	.217109E+05	.576688E+07	-.230782E+07	-.119660E+07
5	80.	.471569E+04	-.490245E+04	-.532600E+05	-.124429E+08	-.933800E+04	.110055E+07
6	80.	-.150075E+04	-.485576E+04	.217109E+05	.576688E+07	-.230782E+07	-.119660E+07
7	80.	-.219310E+04	-.937669E+04	.392429E+05	.138336E+08	-.205169E+07	-.153410E+07
8	80.	-.550942E+03	-.117872E+05	.581250E+05	.235464E+08	-.622978E+06	-.134134E+07
9	80.	.471569E+04	-.490245E+04	-.532600E+05	-.124429E+08	-.933800E+04	.110055E+07
10	80.	0.	0.	0.	0.	0.	0.

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 0.00 MATERIAL PROPERTIES

MATERIAL NUMBER 1, MATID = 4

ALUMINUM ALLOY 2024-T62

COND NO.	TEMP (F)	FTU (KSI)	FCY (KSI)	FSU (KSI)	EC (PSI) (X10E6)	E (PSI) (X10E6)	G (PSI) (X10E6)	RHO (LB/IN3)
1	80.	62.00	49.00	37.00	10.00	10.20	4.00	.1000
2	80.	62.00	49.00	37.00	10.00	10.20	4.00	.1000
3	80.	62.00	49.00	37.00	10.00	10.20	4.00	.1000
4	80.	62.00	49.00	37.00	10.00	10.20	4.00	.1000

MATERIAL NUMBER 2, MATID = 6

7075-T6 EXTRUSION 1.5-3.0 IN-A

COND NO.	TEMP (F)	FTU (KSI)	FCY (KSI)	FSU (KSI)	EC (PSI) (X10E6)	E (PSI) (X10E6)	G (PSI) (X10E6)	RHO (LB/IN3)
1	80.	81.00	72.00	45.00	10.50	10.30	3.90	.1010
2	80.	81.00	72.00	45.00	10.50	10.30	3.90	.1010
3	80.	81.00	72.00	45.00	10.50	10.30	3.90	.1010
4	80.	81.00	72.00	45.00	10.50	10.30	3.90	.1010

MATERIAL NUMBER 3, MATID = 8

TI-6AL-4V, ANNEALED PLATE

COND NO.	TEMP (F)	FTU (KSI)	FCY (KSI)	FSU (KSI)	EC (PSI) (X10E6)	E (PSI) (X10E6)	G (PSI) (X10E6)	RHO (LB/IN3)
1	80.	130.00	126.00	76.00	16.40	16.00	6.20	.1600
2	80.	130.00	126.00	76.00	16.40	16.00	6.20	.1600
3	80.	130.00	126.00	76.00	16.40	16.00	6.20	.1600
4	80.	130.00	126.00	76.00	16.40	16.00	6.20	.1600

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 0.00

PANEL DETAIL GEOMETRIC DATA

PANEL NO.	END NODES	CONST TYPE	MATERIAL NO. SKIN	MATERIAL NO. STIFF	SYMMETRY GROUP	DS	TBAR SKIN	YBAR SKIN	TBAR STIF	YBAR STIF	T1	T2	T3	T4	B1	B2	B3
1	1, 2	5	1	2	1	49.97	.087	.044	.040	.656	.087	.095	.062	.040	6.00	1.50	.32
2	2, 3	5	1	2	1	48.20	.087	.044	.040	.656	.087	.095	.062	.040	6.00	1.50	.32
3	3, 4	5	1	2	1	48.19	.087	.044	.040	.656	.087	.095	.062	.040	6.00	1.50	.32
4	4, 5	5	1	2	1	49.32	.087	.044	.040	.656	.087	.095	.062	.040	6.00	1.50	.32
5	5, 6	21	3	0	3	53.38	.101	0.000	0.000	0.000	.067	.090	0.000	0.000	5.50	1.03	0.00
6	6, 7	5	1	2	2	48.20	.110	.055	.028	.792	.110	.043	.113	.040	7.50	1.50	.56
7	7, 8	5	1	2	2	48.23	.110	.055	.028	.792	.110	.043	.113	.040	7.50	1.50	.56
8	8, 9	5	1	2	2	48.19	.110	.055	.028	.792	.110	.043	.113	.040	7.50	1.50	.56
9	9,10	5	1	2	2	48.18	.110	.055	.028	.792	.110	.043	.113	.040	7.50	1.50	.56
10	10, 1	21	3	0	4	57.83	.111	0.000	0.000	0.000	.071	.098	0.000	0.000	5.50	1.12	0.00

SPAR-CAP DETAIL GEOMETRIC DATA

ELEMENT NO.	NODE	CONST TYPE	MATERIAL NUMBER	SYMMETRY GROUP	ANGLE (DEG)	AREA	YBAR	T1	T2	T3	T4	B1	B2	B3
1	1	2	3	1	0.00	.180	.277	.040	.040	.040	0.000	1.50	1.50	1.50
2	5	2	3	1	0.00	.180	.277	.040	.040	.040	0.000	1.50	1.50	1.50
3	6	2	3	2	180.00	.180	.277	.040	.040	.040	0.000	1.50	1.50	1.50
4	10	2	3	2	180.00	.180	.277	.040	.040	.040	0.000	1.50	1.50	1.50

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 0.00

ELEMENT APPLIED STRESSES

ELEMENT ID(TYPE)		CONDITION 1	2	3	4	5	6	7	8	9	10
PANEL 1 (5)	SX	-18107.	6229.	13966.	-3664.	6983.	-3664.	-8178.	-13297.	6983.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	4868.	-2562.	-6355.	255.	-3177.	255.	1445.	3332.	-3177.	0.
	SXST	-18284.	6290.	14103.	-3700.	7051.	-3700.	-8257.	-13428.	7051.	0.
PANEL 2 (5)	SX	-20708.	8021.	15649.	-3861.	7824.	-3861.	-9025.	-15098.	7824.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	1530.	-1656.	-1503.	-725.	-751.	-725.	-316.	779.	-751.	0.
	SXST	-20911.	8100.	15802.	-3899.	7901.	-3899.	-9113.	-15246.	7901.	0.
PANEL 3 (5)	SX	-19380.	8210.	14314.	-3358.	7157.	-3358.	-8195.	-14044.	7157.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	-1754.	-635.	3084.	-1660.	1542.	-1660.	-2006.	-1722.	1542.	0.
	SXST	-19570.	8290.	14454.	-3391.	7227.	-3391.	-8276.	-14182.	7227.	0.
PANEL 4 (5)	SX	-15583.	7391.	11085.	-2416.	5542.	-2416.	-6313.	-11198.	5542.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	-4815.	446.	7171.	-2501.	3586.	-2501.	-3537.	-4044.	3586.	0.
	SXST	-15736.	7463.	11193.	-2440.	5597.	-2440.	-6374.	-11308.	5597.	0.
PANEL 5 (21)	SX	3078.	933.	-3991.	1321.	-1995.	1321.	2052.	2493.	-1995.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	-8706.	1715.	12194.	-3863.	6097.	-3863.	-5732.	-7093.	6097.	0.
PANEL 6 (5)	SX	16407.	-5666.	-13477.	3281.	-6739.	3281.	7343.	12036.	-6739.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	-3396.	686.	4423.	-1758.	2212.	-1758.	-2433.	-2851.	2212.	0.
	SXST	16568.	-5721.	-13610.	3313.	-6805.	3313.	7415.	12154.	-6805.	0.
PANEL 7 (5)	SX	16810.	-6561.	-13472.	3087.	-6736.	3087.	7253.	12240.	-6736.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	-1061.	70.	1002.	-1068.	501.	-1068.	-1195.	-1063.	501.	0.
	SXST	16975.	-6625.	-13605.	3117.	-6802.	3117.	7324.	12360.	-6802.	0.
PANEL 8 (5)	SX	17068.	-7397.	-13356.	2867.	-6678.	2867.	7101.	12339.	-6678.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	1403.	-695.	-2441.	-366.	-1221.	-366.	73.	814.	-1221.	0.
	SXST	17235.	-7469.	-13487.	2895.	-6743.	2895.	7171.	12460.	-6743.	0.
PANEL 9 (5)	SX	16670.	-7985.	-12736.	2529.	-6368.	2529.	6669.	11961.	-6368.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	
	SXY	3903.	-1581.	-5775.	320.	-2887.	320.	1323.	2710.	-2887.	

	SXST	16833.	-8043.	-12860.	2554.	-6430.	2554.	6734.	12078.	-6430.	0.
PANEL 10 (21)	SX	1212.	-2890.	-584.	-682.	-292.	-682.	-390.	581.	-292.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	9503.	-3919.	-13189.	1397.	-6594.	1397.	3701.	6804.	-6594.	0.
SPAR-CAP 1 (2)	SX	-23022.	7001.	18023.	-4998.	9011.	-4998.	-10735.	-17020.	9011.	0.
SPAR-CAP 2 (2)	SX	-19273.	10056.	13171.	-2660.	6586.	-2660.	-7489.	-13741.	6586.	0.
SPAR-CAP 3 (2)	SX	25429.	-8189.	-21152.	5301.	-10576.	5301.	11594.	18727.	-10576.	0.
SPAR-CAP 4 (2)	SX	25446.	-12781.	-19191.	3634.	-9596.	3634.	9955.	18182.	-9596.	0.

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 0.00

ELEMENT STATIC STRENGTH
MARGINS OF SAFETY

CONDITION		1	2	3	4
ELEMENT ID(TYPE)	SYMMETRY GROUP				
PANEL 1 (5)	1	-.001	4.476	1.353	5.770
STIFFENER		1.897	7.422	2.756	13.318
PANEL 2 (5)	1	.192	3.938	1.656	4.389
STIFFENER		1.533	5.540	2.352	12.587
PANEL 3 (5)	1	.249	4.088	1.753	2.807
STIFFENER		1.707	5.390	2.665	14.621
PANEL 4 (5)	1	.085	4.672	1.505	2.014
STIFFENER		2.366	6.098	3.732	20.714
PANEL 5 (21)	3	.401	6.112	.000	2.157
PANEL 6 (5)	2	1.413	1.552	.055	8.331
STIFFENER		2.197	8.258	2.892	14.987
PANEL 7 (5)	2	1.493	1.209	.075	10.653
STIFFENER		2.121	6.995	2.894	15.994
PANEL 8 (5)	2	1.445	.957	.079	13.348
STIFFENER		2.073	6.092	2.928	17.300
PANEL 9 (5)	2	1.337	.807	-.001	15.266
STIFFENER		2.147	5.586	3.119	19.739
PANEL 10 (21)	4	.387	2.362	-.001	8.434
SPAR-CAP 1 (2)	1	.164	17.115	6.037	4.360
SPAR-CAP 2 (2)	1	.390	11.612	8.630	9.071
SPAR-CAP 3 (2)	2	3.988	2.271	.266	22.925
SPAR-CAP 4 (2)	2	3.984	1.096	.396	33.902

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 0.00

FATIGUE ANALYSIS RESULTS

DESIGN LIFE .... 80000. FLIGHTS
FREQUENCY OF PEAK LOADS ... 2.00 CYCLES/FLIGHT

FATIGUE DAMAGE FOR
SINGLE MATERIAL PANEL SKIN AND STIFFENERS
OR
TWO MATERIAL PANEL SKIN

PANEL NO.	SYMMETRY GROUP	MAXIMUM SPECTRUM STRESS	FATIGUE LIFE (FLIGHTS)	IN FLIGHT DAMAGE	G-A-G DAMAGE	TOTAL DAMAGE	WEIGHT PENALTY (PERCENT)
1	1	12318.	.254E+06	.0000	.3154	.3155	.00
2	1	11844.	.246E+06	.0000	.3254	.3254	.00
3	1	11213.	.319E+06	.0000	.2508	.2508	.00
4	1	10954.	.437E+06	.0000	.1831	.1831	.00
5	3	8448.	.576E+99	.0000	.0000	.0000	.00
6	2	12677.	.468E+06	.0000	.1711	.1711	.00
7	2	12332.	.674E+06	.0000	.1187	.1187	.00
8	2	12392.	.825E+06	.0000	.0969	.0970	.00
9	2	12546.	.815E+06	.0000	.0982	.0982	.00
10	4	7101.	.531+100	.0000	.0000	.0000	.00

FATIGUE DAMAGE FOR
TWO MATERIAL PANEL STIFFENERS

PANEL NO.	SYMMETRY GROUP	MAXIMUM SPECTRUM STRESS	FATIGUE LIFE (FLIGHTS)	IN FLIGHT DAMAGE	G-A-G DAMAGE	TOTAL DAMAGE	WEIGHT PENALTY (PERCENT)
1	1	10577.	.455E+06	.0000	.1760	.1760	.00
2	1	11851.	.245E+06	.0000	.3264	.3264	.00
3	1	10841.	.390E+06	.0000	.2051	.2051	.00
4	1	8395.	.588E+07	.0000	.0136	.0136	.00
6	2	12154.	.789E+06	.0000	.1014	.1014	.00
7	2	12360.	.770E+06	.0000	.1039	.1039	.00
8	2	12460.	.818E+06	.0000	.0978	.0978	.00
9	2	12078.	.124E+07	.0000	.0647	.0647	.00

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 0.00

FLAW GROWTH ANALYSIS RESULTS

INITIAL CRACK SIZE, 2A .... 2.000 INCHES
INSPECTION INTERVAL .... 20000. FLIGHTS

PANEL NO.	SYMMETRY GROUP	MAXIMUM SPECTRUM STRESS SKIN (PSI)	MAXIMUM SPECTRUM STRESS STIFF. (PSI)	CRITICAL INITIAL FLAW SIZE (2A,IN.)	SAFE LIFE (FLIGHTS)	WEIGHT PENALTY (PERCENT)
1	1	9776.	9872.	24.920	.811E+05	.00
2	1	10954.	11061.	17.798	.534E+05	.00
3	1	10020.	10118.	24.384	.741E+05	.00
4	1	7759.	7835.	28.634	.190E+06	.00
5	3	0.	0.	0.000	0.	0.00
6	2	11161.	11270.	32.899	.145E+06	.00
7	2	11325.	11436.	32.727	.140E+06	.00
8	2	11391.	11503.	32.725	.140E+06	.00
9	2	11018.	11126.	33.564	.161E+06	.00
10	4	0.	0.	0.000	0.	0.00

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 0.00

RESIDUAL STRENGTH ANALYSIS RESULTS

DAMAGE CRACK SIZE, 2A ..... 15.000 INCHES
NUMBER OF BROKEN MEMBERS .. 1
DESIGN LOAD WITH DAMAGE ... .85 OF LIMIT LOAD

PANEL NO.	SYMMETRY GROUP	MAXIMUM LIMIT LOAD (LB/IN)	REQUIRED RESIDUAL STRENGTH (LB/IN)	CRITICAL CRACK SIZE (2A,IN.)	ACTUAL RESIDUAL STRENGTH (LB/IN)	WEIGHT PENALTY (PERCENT)
1	1	1789.	1520.	36.000	3036.	.00
2	1	2004	1704.	36.000	3036.	.00
3	1	1833.	1558.	36.000	3036.	.00
4	1	1420.	1207.	36.000	3036.	.00
5	3	0.	0.	0.000	0.	.00
6	2	2261.	1922.	38.026	2509.	.00
7	2	2317.	1969.	35.629	2509.	.00
8	2	2353.	2000.	34.171	2509.	.00
9	2	2298.	1953.	36.447	2509.	.00
10	4	0.	0.	0.000	0.	.00

RIB DESIGN DATA

BUILT-UP WEB CONSTRUCTION

STATION	WEB THICK. (IN.)	CAP AREA (SQ.IN)	CAP LENGTH (IN.)	AVG.RIB HEIGHT (IN.)	NUMBER OF WEB STIFF.	WEB WEIGHT (LBS.)	WEIGHT OF 2 CAPS (LBS.)	TOTAL RIB WT. (LBS.)	MATERIAL NUMBER
0.0	.160	.150	192.71	65.22	2	50.27	5.78	56.05	1

JOB LOG

MODULE	CP TIME	PP TIME	MTR REQUESTS	CALLS
HEADER10	.091	0	0	1
INCON20	.405	0	0	1
STATION30	.016	0	0	1
REDCON41	.620	0	0	7
OPTCON42	4.828	0	0	5
RECFAT43	2.060	0	0	2
RECGRD44	1.099	0	0	3
RECRES45	.029	0	0	1
STADUT50	.157	0	0	1
TOTAL	9.305	0	0	21

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 600.00

SECTION NODAL GEOMETRY

NODE	X	Z	NODE	X	Z	NODE	X	Z
1	32.86	14.38	2	57.51	18.13	3	82.16	19.18
4	106.80	18.65	5	131.45	14.38	6	131.45	-7.19
7	106.80	-7.71	8	82.16	-8.69	9	57.51	-8.99
10	32.86	-8.99						

SECTION PROPERTIES

CENTROID		LOAD REF.		SPACING	TAPER
XCG	ZCG	XLR	ZLR	L	RATIO
82.17	4.29	82.15	0.00	20.00	0.00

EA	EIXX	EIZZ	EIXZ	GJ
.358719E+09	.601400E+11	.312430E+12	.388321E+10	.488006E+11

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 600.00 INPUT LOADS

COND NO.	DESCRIPTION
1	2.5G POSITIVE MANEUVER S-4 WING
2	-1.0G NEGATIVE MANEUVER S-4 WING
3	2.0G TAXI S-4 WING
4	1.0G FLIGHT S-4 WING
5	1.0G TAXI S-4 WING
6	1.0G FLIGHT S-4 WING
7	1.0G FLIGHT +1.0G GUST S-4 WING
8	1.0G FLIGHT PLUS 1.0G MAN. S-4 WING
9	1.0G LANDING IMPACT S-4 WING
10	MAXIMUM CABIN PRESSURE S-4 WING

COND NO.	TEMP (F)	XSHEAR PX (LB)	AXIAL PY (LB)	ZSHEAR PZ (LB)	XMOMENT MX (IN-LB)	TORSION MY (IN-LB)	ZMOMENT MZ (IN-LB)
1	80.	-.193050E+04	-.597202E+04	.499166E+05	.117051E+08	.424397E+06	-.751814E+06
2	80.	-.258181E+04	.115072E+03	-.229152E+05	-.511780E+07	-.153979E+07	-.221588E+06
3	80.	.321268E+04	-.269578E+04	-.328339E+05	-.498576E+07	-.610869E+06	.437594E+06
4	80.	-.143291E+04	-.221746E+04	.568629E+04	.152867E+07	-.124904E+07	-.322728E+06
5	80.	.160634E+04	-.134789E+04	-.164170E+05	-.249290E+07	-.305386E+06	.218739E+06
6	80.	-.143291E+04	-.221746E+04	.568629E+04	.152867E+07	-.124904E+07	-.322728E+06
7	80.	-.187863E+04	-.379124E+04	.185046E+05	.439559E+07	-.891628E+06	-.428305E+06
8	80.	-.176473E+04	-.472164E+04	.351878E+05	.831641E+07	-.133037E+06	-.609230E+06
9	80.	.160634E+04	-.134789E+04	-.164170E+05	-.249290E+07	-.305386E+06	.218739E+06
10	80.	0.	0.	0.	0.	0.	0.

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 600.00 MATERIAL PROPERTIES

MATERIAL NUMBER 1, MATID = 4

ALUMINUM ALLOY 2024-T62

COND NO.	TEMP (F)	FTU (KSI)	FCY (KSI)	FSU (KSI)	EC (PSI) (X10E6)	E (PSI) (X10E6)	G (PSI) (X10E6)	RHO (LB/IN3)
1	80.	62.00	49.00	37.00	10.00	10.20	4.00	.1000
2	80.	62.00	49.00	37.00	10.00	10.20	4.00	.1000
3	80.	62.00	49.00	37.00	10.00	10.20	4.00	.1000
4	80.	62.00	49.00	37.00	10.00	10.20	4.00	.1000

MATERIAL NUMBER 2, MATID = 6

7075-T6 EXTRUSION 1.5-3.0 IN-A

COND NO.	TEMP (F)	FTU (KSI)	FCY (KSI)	FSU (KSI)	EC (PSI) (X10E6)	E (PSI) (X10E6)	G (PSI) (X10E6)	RHO (LB/IN3)
1	80.	81.00	72.00	45.00	10.50	10.30	3.90	.1010
2	80.	81.00	72.00	45.00	10.50	10.30	3.90	.1010
3	80.	81.00	72.00	45.00	10.50	10.30	3.90	.1010
4	80.	81.00	72.00	45.00	10.50	10.30	3.90	.1010

MATERIAL NUMBER 3, MATID = 8

TI-6AL-4V, ANNEALED PLATE

COND NO.	TEMP (F)	FTU (KSI)	FCY (KSI)	FSU (KSI)	EC (PSI) (X10E6)	E (PSI) (X10E6)	G (PSI) (X10E6)	RHO (LB/IN3)
1	80.	130.00	126.00	76.00	16.40	16.00	6.20	.1600
2	80.	130.00	126.00	76.00	16.40	16.00	6.20	.1600
3	80.	130.00	126.00	76.00	16.40	16.00	6.20	.1600
4	80.	130.00	126.00	76.00	16.40	16.00	6.20	.1600

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 600.00

PANEL DETAIL GEOMETRIC DATA

PANEL NO.	END NODES	CONST TYPE	MATERIAL NO. SKIN	MATERIAL NO. STIFF	SYMMETRY GROUP	DS	TBAR SKIN	YBAR SKIN	TBAR STIF	YBAR STIF	T1	T2	T3	T4	B1	B2	B3
1	1, 2	5	1	2	1	24.93	.104	.052	.061	.702	.104	.176	.127	.044	6.00	1.50	.10
2	2, 3	5	1	2	1	24.67	.104	.052	.061	.702	.104	.176	.127	.044	6.00	1.50	.10
3	3, 4	5	1	2	1	24.65	.104	.052	.061	.702	.104	.176	.127	.044	6.00	1.50	.10
4	4, 5	5	1	2	1	25.02	.104	.052	.061	.702	.104	.176	.127	.044	6.00	1.50	.10
5	5, 6	21	3	0	3	21.58	.084	0.000	0.000	0.000	.067	.077	0.000	0.000	5.50	.60	0.00
6	6, 7	5	1	2	2	24.65	.125	.062	.051	.822	.125	.078	.207	.070	7.50	1.50	.60
7	7, 8	5	1	2	2	24.66	.125	.062	.051	.822	.125	.078	.207	.070	7.50	1.50	.60
8	8, 9	5	1	2	2	24.65	.125	.062	.051	.822	.125	.078	.207	.070	7.50	1.50	.60
9	9,10	5	1	2	2	24.65	.125	.062	.051	.822	.125	.078	.207	.070	7.50	1.50	.60
10	10, 1	21	3	0	4	23.37	.098	0.000	0.000	0.000	.075	.087	0.000	0.000	5.50	.87	0.00

SPAR-CAP DETAIL GEOMETRIC DATA

ELEMENT NO.	NODE	CONST TYPE	MATERIAL NUMBER	SYMMETRY GROUP	ANGLE (DEG)	AREA	YBAR	T1	T2	T3	T4	B1	B2	B3
1	1	2	3	1	0.00	.237	.285	.053	.053	.053	0.000	1.50	1.50	1.50
2	5	2	3	1	0.00	.237	.285	.053	.053	.053	0.000	1.50	1.50	1.50
3	6	2	3	2	180.00	.180	.277	.040	.040	.040	0.000	1.50	1.50	1.50
4	10	2	3	2	180.00	.180	.277	.040	.040	.040	0.000	1.50	1.50	1.50

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 600.00

ELEMENT APPLIED STRESSES

ELEMENT ID(TYPE)		CONDITION 1	2	3	4	5	6	7	8	9	10
PANEL 1 (5)	SX	-25798.	10530.	10985.	-3687.	5492.	-3687.	-9912.	-18436.	5492.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	7711.	-8177.	-5625.	-1590.	-2812.	-1590.	856.	4614.	-2812.	0.
	SXST	-26051.	10633.	11092.	-3723.	5546.	-3723.	-10009.	-18617.	5546.	0.
PANEL 2 (5)	SX	-29355.	12526.	12408.	-3972.	6203.	-3972.	-11131.	-20903.	6203.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	3053.	-4152.	-2497.	-2161.	-1248.	-2161.	-909.	1317.	-1248.	0.
	SXST	-29643.	12648.	12527.	-4011.	6264.	-4011.	-11240.	-21108.	6264.	0.
PANEL 3 (5)	SX	-28659.	12664.	12015.	-3700.	6007.	-3700.	-10752.	-20348.	6007.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	1811.	-1923.	705.	-2716.	353.	-2716.	-2713.	-2113.	353.	0.
	SXST	-28940.	12788.	12133.	-3737.	6066.	-3737.	-10858.	-20547.	6066.	0.
PANEL 4 (5)	SX	-22674.	10493.	9370.	-2737.	4685.	-2737.	-8386.	-16035.	4685.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	-6277.	233.	3583.	-3188.	1792.	-3188.	-4333.	-5249.	1792.	0.
	SXST	-22896.	10596.	9462.	-2764.	4731.	-2764.	-8469.	-16192.	4731.	0.
PANEL 5 (21)	SX	5694.	-1210.	-2956.	1247.	-1478.	1247.	2438.	4214.	-1478.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	-13061.	2161.	7598.	-5223.	3799.	-5223.	-7859.	-10451.	3799.	0.
PANEL 6 (5)	SX	24991.	-10320.	-10939.	3500.	-5469.	3500.	9521.	17835.	-5469.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	-4548.	165.	2370.	-2486.	1185.	-2486.	-3267.	-3862.	1185.	0.
	SXST	25236.	-10421.	-11046.	3534.	-5523.	3534.	9614.	18010.	-5523.	0.
PANEL 7 (5)	SX	25270.	-10884.	-10963.	3356.	-5481.	3356.	9508.	17973.	-5481.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	-862.	-1427.	-110.	-2031.	-55.	-2031.	-1867.	-1252.	-55.	0.
	SXST	25517.	-10991.	-11070.	3388.	-5535.	3388.	9601.	18149.	-5535.	0.
PANEL 8 (5)	SX	25324.	-11350.	-10892.	3182.	-5446.	3182.	9411.	17951.	-5446.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	2926.	-3163.	-2604.	-1598.	-1302.	-1598.	-462.	1419.	-1302.	0.
	SXST	25572.	-11461.	-10999.	3213.	-5499.	3213.	9503.	18127.	-5499.	0.
PANEL 9 (5)	SX	24403.	-11390.	-10405.	2881.	-5202	2881.	8948.	17236.	-5202.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	
	SXY	6670.	-4976.	-5014.	-1204.	-2507.	-1204.	895.	4048.	-2507.	

	SXST	24642.	-11502.	-10507.	2909.	-5253.	2909.	9035.	17405.	-5253.	0.
PANEL 10 (21)	SX	876.	-1882.	-311.	-516.	-156.	-516.	-108.	412.	-156.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	15397.	-165[illegible].	-11019.	-1603.	-5509.	-1603.	2996.	9735.	-5509.	0.
SPAR-CAP 1 (2)	SX	-34685.	13645.	14841.	-5169.	7420.	-5169.	-13468.	-24857.	7420.	0.
SPAR-CAP 2 (2)	SX	-27067.	13095.	11003.	-3039.	5502.	-3039.	-9870.	-19065.	5502.	0.
SPAR-CAP 3 (2)	SX	38481.	-15526.	-16925.	5537.	-8463.	5537.	14756.	27512.	-8463.	0.
SPAR-CAP 4 (2)	SX	36483.	-17421.	-15474.	4140.	-7737.	4140.	13281.	25899.	-7737.	0.

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 600.00

ELEMENT STATIC STRENGTH
MARGINS OF SAFETY

ELEMENT ID(TYPE)	SYMMETRY GROUP	CONDITION 1	2	3	4
PANEL 1 (5)	1	-.015	1.780	1.846	4.559
STIFFENER		1.033	3.982	3.776	13.257
PANEL 2 (5)	1	.225	1.904	2.202	3.404
STIFFENER		.787	3.188	3.228	12.207
PANEL 3 (5)	1	.324	2.215	2.490	2.775
STIFFENER		.830	3.142	3.366	13.176
PANEL 4 (5)	1	.165	3.015	2.728	2.486
STIFFENER		1.314	3.999	4.598	18.168
PANEL 5 (21)	3	-.011	4.981	.701	1.474
PANEL 6 (5)	2	.606	1.773	1.129	6.508
STIFFENER		1.099	4.083	3.796	13.989
PANEL 7 (5)	2	.665	1.405	1.613	7.583
STIFFENER		1.076	3.820	3.785	14.633
PANEL 8 (5)	2	.631	.873	1.069	8.911
STIFFENER		1.071	3.622	3.816	15.485
PANEL 9 (5)	2	.556	.494	.542	10.772
STIFFENER		1.150	3.606	4.042	17.208
PANEL 10 (21)	4	.018	.491	.423	8.779
SPAR-CAP 1 (2)	1	-.035	8.295	7.546	5.477
SPAR-CAP 2 (2)	1	.237	8.685	10.527	10.015
SPAR-CAP 3 (2)	2	2.296	.725	.583	21.906
SPAR-CAP 4 (2)	2	2.478	.538	.731	29.834

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 600.00

FATIGUE ANALYSIS RESULTS

DESIGN LIFE .... 80000. FLIGHTS
FREQUENCY OF PEAK LOADS ... 2.00 CYCLES/FLIGHT

FATIGUE DAMAGE FOR
SINGLE MATERIAL PANEL SKIN AND STIFFENERS
OR
TWO MATERIAL PANEL SKIN

PANEL NO.	SYMMETRY GROUP	MAXIMUM SPECTRUM STRESS	FATIGUE LIFE (FLIGHTS)	IN FLIGHT DAMAGE	G-A-G DAMAGE	TOTAL DAMAGE	WEIGHT PENALTY (PERCENT)
1	1	10015.	.564E+08	.0000	.0014	.0014	.00
2	1	9667.	.122E+09	.0001	.0006	.0007	.00
3	1	9042.	.185E+09	.0000	.0004	.0004	.00
4	1	7938.	.643E+08	.0000	.0012	.0012	.00
5	3	12768.	.576E+99	.0000	.0000	.0000	.00
6	2	18635.	.244E+06	.0011	.3265	.3276	.00
7	2	18059.	.301E+06	.0010	.2650	.2660	.00
8	2	18062.	.296E+06	.0014	.2689	.2704	.00
9	2	18139.	.272E+06	.0021	.2921	.2942	.00
10	4	9943.	.164+100	.0000	.0000	.0000	.00

FATIGUE DAMAGE FOR
TWO MATERIAL PANEL STIFFENERS

PANEL NO.	SYMMETRY GROUP	MAXIMUM SPECTRUM STRESS	FATIGUE LIFE (FLIGHTS)	IN FLIGHT DAMAGE	G-A-G DAMAGE	TOTAL DAMAGE	WEIGHT PENALTY (PERCENT)
1	1	9681.	.137E+10	.0001	.0000	.0001	.00
2	1	11376.	.341E+09	.0002	.0000	.0002	.00
3	1	11393.	.381E+09	.0002	.0000	.0002	.00
4	1	9322.	.166E+10	.0000	.0000	.0000	.00
6	2	18010.	.328E+06	.0018	.2424	.2442	.00
7	2	18149.	.325E+06	.0021	.2444	.2465	.00
8	2	18127.	.335E+06	.0025	.2366	.2391	.00
9	2	17405.	.426E+06	.0017	.1863	.1880	.00

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 600.00

FLAW GROWTH ANALYSIS RESULTS

INITIAL CRACK SIZE, 2A .... 2.000 INCHES
INSPECTION INTERVAL .... 20000. FLIGHTS

PANEL NO.	SYMMETRY GROUP	MAXIMUM SPECTRUM STRESS SKIN (PSI)	MAXIMUM SPECTRUM STRESS STIFF. (PSI)	CRITICAL INITIAL FLAW SIZE (2A,IN.)	SAFE LIFE (FLIGHTS)	WEIGHT PENALTY (PERCENT)
1	1	7689.	7765.	29.382	.222E+06	.00
2	1	8684.	8769.	27.444	.142E+06	.00
3	1	8410.	8493.	27.951	.160E+06	.00
4	1	6559.	6624.	31.859	.398E+06	.00
5	3	0.	0.	0.000	0.	0.00
6	2	16402.	16562.	22.604	.591E+05	13.01
7	2	16511.	16673.	22.322	.583E+05	13.01
8	2	16474.	16636.	22.943	.597E+05	13.01
9	2	15800.	15955.	28.632	.707E+05	13.01
10	4	0.	0.	0.000	0.	0.00

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 600.00

RESIDUAL STRENGTH ANALYSIS RESULTS

DAMAGE CRACK SIZE, 2A ..... 15.000 INCHES
NUMBER OF BROKEN MEMBERS .. 1
DESIGN LOAD WITH DAMAGE ... .85 OF LIMIT LOAD

PANEL NO.	SYMMETRY GROUP	MAXIMUM LIMIT LOAD (LB/IN)	REQUIRED RESIDUAL STRENGTH (LB/IN)	CRITICAL CRACK SIZE (2A,IN.)	ACTUAL RESIDUAL STRENGTH (LB/IN)	WEIGHT PENALTY (PERCENT)
1	1	1823.	1550.	36.000	4224.	.00
2	1	2079.	1767.	36.000	4224.	.00
3	1	2102.	1787.	36.000	4224.	.00
4	1	1742.	1480.	36.000	4224.	.00
5	3	0.	0.	0.000	0.	.00
6	2	4405.	3744.	33.864	3796.	11.70
7	2	4454.	3786.	31.964	3796.	11.70
8	2	4464.	3794.	31.605	3796.	11.70
9	2	4301.	3656.	35.023	3796.	11.70
10	4	0.	0.	0.000	0.	.00

RIB DESIGN DATA

BUILT-UP WEB CONSTRUCTION

STATION	WEB THICK. (IN.)	CAP AREA (SQ.IN)	CAP LENGTH (IN.)	AVG.RIB HEIGHT (IN.)	NUMBER OF WEB STIFF.	WEB WEIGHT (LBS.)	WEIGHT OF 2 CAPS (LBS.)	TOTAL RIB WT. (LBS.)	MATERIAL NUMBER
600.0	.160	.150	98.59	25.96	3	10.24	2.96	13.19	1

JOB LOG

MODULE	CP TIME	PP TIME	MTR REQUESTS	CALLS
HEADER10	.091	0	0	1
INCON20	.405	0	0	1
STATION30	.026	0	0	2
REDCON41	1.099	0	0	13
OPTCON42	7.291	0	0	9
RECFAT43	4.078	0	0	4
RECGRD44	2.966	0	0	4
RECRES45	.111	0	0	2
STADUT50	.365	0	0	2
TOTOUT	.101	0	0	1
TOTAL	16.533	0	0	39

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 1123.80

SECTION NODAL GEOMETRY

NODE	X	Z	NODE	X	Z	NODE	X	Z
1	15.75	5.10	2	27.55	8.43	3	39.36	6.81
4	51.17	8.62	5	62.98	5.10	6	62.98	-2.55
7	51.17	-2.74	8	39.36	-3.08	9	27.55	-3.19
10	16.75	-3.19						

SECTION PROPERTIES

CENTROID		LOAD REF.		SPACING	TAPER
XCG	ZCG	XLR	ZLR	L	RATIO
39.61	2.24	39.36	0.00	20.00	0.00

EA	EIXX	EIZZ	EIXZ	GJ
.109680E+09	.271455E+10	.242565E+11	.722307E+08	.257905E+10

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 1123.80 INPUT LOADS

COND NO.	DESCRIPTION
1	2.5G POSITIVE MANEUVER S-4 WING
2	-1.0G NEGATIVE MANEUVER S-4 WING
3	2.0G TAXI S-4 WING
4	1.0G FLIGHT S-4 WING
5	1.0G TAXI S-4 WING
6	1.0G FLIGHT S-4 WING
7	1.0G FLIGHT +1.0G GUST S-4 WING
8	1.0G FLIGHT PLUS 1.0G MAN. S-4 WING
9	1.0G LANDING IMPACT S-4 WING
10	MAXIMUM CABIN PRESSURE S-4 WING

COND NO.	TEMP (F)	XSHEAR PX (LB)	AXIAL PY (LB)	ZSHEAR PZ (LB)	XMOMENT MX (IN-LB)	TORSION MY (IN-LB)	ZMOMENT MZ (IN-LB)
1	80.	-.485667E+03	-.402844E+03	.814608E+04	.157962E+06	.327100E+05	-.137077E+05
2	80.	.302546E+03	.233763E+03	-.380685E+04	-.414864E+05	-.107033E+06	.886096E+04
3	80.	.669333E+02	-.535566E+02	-.662728E+03	-.185831E+05	.321322E+04	.209218E+04
4	80.	.671753E+01	-.133422E+02	-.252862E+03	.320944E+05	-.614578E+05	.670673E+03
5	80.	.334667E+02	-.267783E+02	-.331364E+03	-.945813E+04	.133983E+04	.134610E+04
6	80.	.671753E+01	-.133422E+02	-.252862E+03	.320944E+05	-.614578E+05	.670673E+03
7	80.	-.314311E+02	-.581545E+02	.137516E+04	.670917E+05	-.420783E+05	-.676291E+03
8	80.	-.321984E+03	-.273232E+03	.401533E+04	.116228E+06	.136533E+04	-.873711E+04
9	80.	.334667E+02	-.267783E+02	-.331364E+03	-.945813E+04	.133983E+04	.134610E+04
10	80.	0.	0.	0.	0.	0.	0.

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 1123.80 MATERIAL PROPERTIES

MATERIAL NUMBER 1, MATID = 4

ALUMINUM ALLOY 2024-T62

COND NO.	TEMP (F)	FTU (KSI)	FCY (KSI)	FSU (KSI)	EC (PSI) (X10E6)	E (PSI) (X10E6)	G (PSI) (X10E6)	RHO (LB/IN3)
1	80.	62.00	49.00	37.00	10.00	10.20	4.00	.1000
2	80.	62.00	49.00	37.00	10.00	10.20	4.00	.1000
3	80.	62.00	49.00	37.00	10.00	10.20	4.00	.1000
4	80.	62.00	49.00	37.00	10.00	10.20	4.00	.1000

MATERIAL NUMBER 2, MATID = 6

7075-T6 EXTRUSION 1.5-3.0 IN-A

COND NO.	TEMP (F)	FTU (KSI)	FCY (KSI)	FSU (KSI)	EC (PSI) (X10E6)	E (PSI) (X10E6)	G (PSI) (X10E6)	RHO (LB/IN3)
1	80.	81.00	72.00	45.00	10.50	10.30	3.90	.1010
2	80.	81.00	72.00	45.00	10.50	10.30	3.90	.1010
3	80.	81.00	72.00	45.00	10.50	10.30	3.90	.1010
4	80.	81.00	72.00	45.00	10.50	10.30	3.90	.1010

MATERIAL NUMBER 3, MATID = 8

TI-6AL-4V, ANNEALED PLATE

COND NO.	TEMP (F)	FTU (KSI)	FCY (KSI)	FSU (KSI)	EC (PSI) (X10E6)	E (PSI) (X10E6)	G (PSI) (X10E6)	RHO (LB/IN3)
1	80.	130.00	126.00	76.00	16.40	16.00	6.20	.1600
2	80.	130.00	126.00	76.00	16.40	16.00	6.20	.1600
3	80.	130.00	126.00	76.00	16.40	16.00	6.20	.1600
4	80.	130.00	126.00	76.00	16.40	16.00	6.20	.1600

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 1123.80

PANEL DETAIL GEOMETRIC DATA

PANEL NO.	END NODES	CONST TYPE	MATERIAL NO. SKIN	MATERIAL NO. STIFF	SYMMETRY GROUP	DS	TBAR SKIN	YBAR SKIN	TBAR STIF	YBAR STIF	T1	T2	T3	T4	B1	B2	B3
1	1, 2	5	1	2	1	12.26	.080	.040	.024	.445	.080	.040	.040	.040	6.00	1.50	.10
2	2, 3	5	1	2	1	11.92	.080	.040	.024	.445	.080	.040	.040	.040	6.00	1.50	.10
3	3, 4	5	1	2	1	11.95	.080	.040	.024	.445	.080	.040	.040	.040	6.00	1.50	.10
4	4, 5	5	1	2	1	12.32	.080	.040	.024	.445	.080	.040	.040	.040	6.00	1.50	.10
5	5, 6	21	3	0	3	7.65	.051	0.000	0.000	0.000	.042	.048	0.000	0.000	5.50	.50	0.00
6	6, 7	5	1	2	2	11.81	.080	.040	.019	.416	.080	.040	.040	.040	7.50	1.50	.01
7	7, 8	5	1	2	2	11.81	.080	.040	.019	.416	.080	.040	.040	.040	7.50	1.50	.01
8	8, 9	5	1	2	2	11.81	.080	.040	.019	.416	.080	.040	.040	.040	7.50	1.50	.01
9	9,10	5	1	2	2	10.80	.080	.040	.019	.416	.080	.040	.040	.040	7.50	1.50	.01
10	10, 1	21	3	0	4	8.35	.055	0.000	0.000	0.000	.046	.052	0.000	0.000	5.50	.50	0.00

SPAR-CAP DETAIL GEOMETRIC DATA

ELEMENT NO.	NODE	CONST TYPE	MATERIAL NUMBER	SYMMETRY GROUP	ANGLE (DEG)	AREA	YBAR	T1	T2	T3	T4	B1	B2	B3
1	1	2	3	1	0.00	.180	.277	.040	.040	.040	0.000	1.50	1.50	1.50
2	5	2	3	1	0.00	.180	.277	.040	.040	.040	0.000	1.50	1.50	1.50
3	6	2	3	2	180.00	.180	.277	.040	.040	.040	0.000	1.50	1.50	1.50
4	10	2	3	2	180.00	.180	.277	.040	.040	.040	0.000	1.50	1.50	1.50

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 1123.80

ELEMENT APPLIED STRESSES

CONDITION		1	2	3	4	5	6	7	8	9	10
ELEMENT ID(TYPE)											
PANEL 1 (5)	SX	-2860.	803.	331.	-548.	171.	-548.	-1165.	-2092.	171.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	3302.	-3179.	-267.	-923.	-137.	-923.	98.	1895.	-137.	0.
	SXST	-2888.	811.	334.	-554.	172.	-554.	-1176.	-2112.	172.	0.
PANEL 2 (5)	SX	-3279.	887.	378.	-651.	193.	-651.	-1368.	-2407.	193.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	1237.	-1901.	-43.	-839.	-25.	-839.	-358.	546.	-25.	0.
	SXST	-3311.	896.	381.	-657.	195.	-657.	-1382.	-2430.	195.	0.
PANEL 3 (5)	SX	-3246.	852.	371.	-661.	188.	-661.	-1380.	-2389.	188.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	-545.	-796.	149.	-765.	71.	-765.	-757.	-619.	71.	0.
	SXST	-3278.	861.	375.	-668.	190.	-668.	-1394.	-2413.	190.	0.
PANEL 4 (5)	SX	-2649.	669.	299.	-557.	150.	-557.	-1152.	-1957.	150.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	-2567.	456.	366.	-681.	179.	-681.	-1215.	-1939.	179.	0.
	SXST	-2675.	676.	302.	-563.	152.	-563.	-1164.	-1976.	152.	0.
PANEL 5 (21)	SX	1115.	-355.	-153.	183.	-82.	183.	411.	803.	-82.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	-6195.	1687.	834.	-1234.	410.	-1234.	-2616.	-4543.	410.	0.
PANEL 6 (5)	SX	2994.	-813.	-365.	589.	-188.	589.	1244.	2195.	-188.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	-2141.	191.	317.	-696.	155.	-696.	-1135.	-1659.	155.	0.
	SXST	3023.	-821.	-369.	595.	-190.	595.	1258.	2217.	-190.	0.
PANEL 7 (5)	SX	3062.	-805.	-371.	620.	-189.	620.	1299.	2252.	-189.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	-422.	-874.	131.	-766.	62.	-766.	-756.	-536.	62.	0.
	SXST	3092.	-813.	-374.	626.	-191.	626.	1311.	2274.	-191.	0.
PANEL 8 (5)	SX	3107.	-791.	-374.	646.	-189.	646.	1343.	2292.	-189.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	1349.	-1970.	-60.	-839.	-34.	-839.	-360.	621.	-34.	0.
	SXST	3138.	-799.	-377.	653.	-191.	653.	1356.	2314.	-191.	0.
PANEL 9 (5)	SX	3055.	-752.	-365.	652.	-184.	652.	1345.	2260.	-184.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	[illegible]
	SXY	3039.	-3017.	-242.	-909.	-124.	-909.	23.	1725.	-124.	[illegible]

	SXST	3085.	-759.	-369.	659.	-186.	659.	1359.	2282.	-186.	0.
PANEL 10 (21)	SX	861.	-127.	-109.	238.	-51.	238.	461.	658.	-51.	0.
	SY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	SXY	7244.	-6465.	-629.	-1667.	-320.	-1667.	490.	4277.	-320.	0.
SPAR-CAP 1 (2)	SX	-2747.	823.	316.	-494.	165.	-494.	-1069.	-1997.	165.	0.
SPAR-CAP 2 (2)	SX	-2189.	513.	235.	-488.	116.	-488.	-993.	-1628.	116.	0.
SPAR-CAP 3 (2)	SX	4420.	-1224.	-542.	855.	-280.	855.	1814.	3235.	-280.	0.
SPAR-CAP 4 (2)	SX	4470.	-1076.	-533.	970.	-267.	970.	1992.	3313.	-267.	0.

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 1123.80

ELEMENT STATIC STRENGTH
MARGINS OF SAFETY

CONDITION		1	2	3	4
ELEMENT ID(TYPE)	SYMMETRY GROUP				
PANEL 1 (5)	1	.786	4.891	69.144	5.883
STIFFENER		17.342	64.324	157.621	94.651
PANEL 2 (5)	1	2.056	8.855	100.000	6.205
STIFFENER		15.000	58.144	137.925	79.626
PANEL 3 (5)	1	2.708	22.521	91.606	6.709
STIFFENER		15.160	60.550	140.248	78.340
PANEL 4 (5)	1	1.196	39.256	50.181	7.770
STIFFENER		18.799	77.365	174.554	93.153
PANEL 5 (21)	3	-.001	2.670	6.422	4.018
PANEL 6 (5)	2	7.072	10.837	11.121	23.826
STIFFENER		16.520	63.494	142.653	88.041
PANEL 7 (5)	2	12.377	3.594	20.719	21.564
STIFFENER		16.129	64.147	140.458	83.583
PANEL 8 (5)	2	9.768	1.251	27.801	19.604
STIFFENER		15.883	65.332	139.372	80.152
PANEL 9 (5)	2	4.685	.513	13.865	18.007
STIFFENER		16.173	68.754	142.621	79.435
PANEL 10 (21)	4	-.002	.118	10.495	3.336
SPAR-CAP 1 (2)	1	8.750	100.000	100.000	53.265
SPAR-CAP 2 (2)	1	11.236	100.000	100.000	53.900
SPAR-CAP 3 (2)	2	27.693	20.891	48.411	100.000
SPAR-CAP 4 (2)	2	27.373	23.886	49.222	100.000

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 1123.80

FATIGUE ANALYSIS RESULTS

DESIGN LIFE .... 80000. FLIGHTS
FREQUENCY OF PEAK LOADS ... 2.00 CYCLES/FLIGHT

FATIGUE DAMAGE FOR
SINGLE MATERIAL PANEL SKIN AND STIFFENERS
OR
TWO MATERIAL PANEL SKIN

PANEL NO.	SYMMETRY GROUP	MAXIMUM SPECTRUM STRESS	FATIGUE LIFE (FLIGHTS)	IN FLIGHT DAMAGE	G-A-G DAMAGE	TOTAL DAMAGE	WEIGHT PENALTY (PERCENT)
1	1	540.	.381E+99	.0000	.0000	.0000	.00
2	1	294.	.379E+99	.0000	.0000	.0000	.00
3	1	318.	.379E+99	.0000	.0000	.0000	.00
4	1	908.	.381E+99	.0000	.0000	.0000	.00
5	3	4962.	.576E+99	.0000	.0000	.0000	.00
6	2	3087.	.576E+99	.0000	.0000	.0000	.00
7	2	2373.	.576E+99	.0000	.0000	.0000	.00
8	2	2449.	.576E+99	.0000	.0000	.0000	.00
9	2	3191.	.576E+99	.0000	.0000	.0000	.00
10	4	4619.	.576E+99	.0000	.0000	.0000	.00

FATIGUE DAMAGE FOR
TWO MATERIAL PANEL STIFFENERS

PANEL NO.	SYMMETRY GROUP	MAXIMUM SPECTRUM STRESS	FATIGUE LIFE (FLIGHTS)	IN FLIGHT DAMAGE	G-A-G DAMAGE	TOTAL DAMAGE	WEIGHT PENALTY (PERCENT)
1	1	849.	.381E+99	.0000	.0000	.0000	.00
2	1	939.	.381E+99	.0000	.0000	.0000	.00
3	1	903.	.381E+99	.0000	.0000	.0000	.00
4	1	710.	.381E+99	.0000	.0000	.0000	.00
6	2	2217.	.576E+99	.0000	.0000	.0000	.00
7	2	2274.	.576E+99	.0000	.0000	.0000	.00
8	2	2314.	.576E+99	.0000	.0000	.0000	.00
9	2	2282.	.576E+99	.0000	.0000	.0000	.00

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 1123.80

FLAW GROWTH ANALYSIS RESULTS

INITIAL CRACK SIZE, 2A .... 2.000 INCHES
INSPECTION INTERVAL .... 20000. FLIGHTS

PANEL NO.	SYMMETRY GROUP	MAXIMUM SPECTRUM STRESS SKIN (PSI)	MAXIMUM SPECTRUM STRESS STIFF. (PSI)	CRITICAL INITIAL FLAW SIZE (2A,IN.)	SAFE LIFE (FLIGHTS)	WEIGHT PENALTY (PERCENT)
1	1	239.	241.	36.000	.191E+12	.00
2	1	270.	273.	36.000	.121E+12	.00
3	1	264.	266.	36.000	.132E+12	.00
4	1	210.	212.	36.000	.306E+12	.00
5	3	0.	0.	0.000	0.	0.00
6	2	2035.	2055.	44.961	.112E+09	.00
7	2	2089.	2110.	44.956	.941E+08	.00
8	2	2127.	2148.	44.952	.877E+08	.00
9	2	2099.	2119.	44.954	.916E+08	.00
10	4	0.	0.	0.000	0.	0.00

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STATION 1123.80

RESIDUAL STRENGTH ANALYSIS RESULTS

DAMAGE CRACK SIZE, 2A ..... 15.000 INCHES
NUMBER OF BROKEN MEMBERS .. 1
DESIGN LOAD WITH DAMAGE ... .85 OF LIMIT LOAD

PANEL NO.	SYMMETRY GROUP	MAXIMUM LIMIT LOAD (LB/IN)	REQUIRED RESIDUAL STRENGTH (LB/IN)	CRITICAL CRACK SIZE (2A,IN.)	ACTUAL RESIDUAL STRENGTH (LB/IN)	WEIGHT PENALTY (PERCENT)
1	1	84.	71.	36.000	2166.	.00
2	1	92.	79.	36.000	2166.	.00
3	1	89.	76.	36.000	2166.	.00
4	1	70.	59.	36.000	2166.	.00
5	3	0.	0.	0.000	0.	.00
6	2	296.	252.	45.000	1766.	.00
7	2	303.	257.	45.000	1766.	.00
8	2	307.	261.	45.000	1766.	.00
9	2	302.	257.	45.000	1766.	.00
10	4	0.	0.	0.000	0.	.00

RIB DESIGN DATA

BUILT-UP WEB CONSTRUCTION

STATION	WEB THICK. (IN.)	CAP AREA (SQ.IN)	CAP LENGTH (IN.)	AVG.RIB HEIGHT (IN.)	NUMBER OF WEB STIFF.	WEB WEIGHT (LBS.)	WEIGHT OF 2 CAPS (LBS.)	TOTAL RIB WT. (LBS.)	MATERIAL NUMBER
1123.8	.160	.150	47.23	10.12	4	1.91	1.42	3.33	1

JOB LOG

MODULE	CP TIME	PP TIME	MTR REQUESTS	CALLS
HEADER10	.091	0	0	1
INCON20	.405	0	0	1
STATION30	.036	0	0	3
REDCON41	1.728	0	0	19
OPTCON42	7.975	0	0	13
RECFAT43	6.037	0	0	6
RECGRD44	3.952	0	0	6
RECRES45	.139	0	0	3
STAOUT50	.539	0	0	3
TOTOUT	.206	0	0	2
TOTAL	21.108	0	0	57

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

WEIGHT SUMMARY FOR 58 STATIONS

STA ID		STATION NO.	PANEL RUNNING WEIGHT	INTERIOR WEB RUN. WEIGHT	SPAR-CAP/ LONGERON RUN. WT.	PANEL WEIGHT	INTERIOR WEB WEIGHT	SPAR-CAP/ LONGERON WEIGHT	TOTAL BAY WEIGHT
--	-	(IN)	(LB/IN)	(LB/IN)	(LB/IN)	(LBS)	(LBS)	(LBS)	(LBS)
1		0.000	7.046	0.000	.115	139.91	0.00	2.31	142.22
2	*	20.000	6.945	0.000	.116	137.88	0.00	2.32	140.20
3	*	40.000	6.843	0.000	.116	135.82	0.00	2.33	138.16
4	*	60.000	6.739	0.000	.117	133.74	0.00	2.35	136.09
5	*	80.000	6.635	0.000	.118	131.64	0.00	2.36	134.00
6	*	100.000	6.529	0.000	.118	129.52	0.00	2.37	131.89
7	*	120.000	6.423	0.000	.119	127.39	0.00	2.38	129.77
8	*	140.000	6.316	0.000	.119	125.23	0.00	2.40	127.63
9	*	160.000	6.208	0.000	.120	123.05	0.00	2.41	125.46
10	*	180.000	6.098	0.000	.121	120.84	0.00	2.42	123.26
11	*	200.000	5.987	0.000	.121	118.61	0.00	2.43	121.04
12	*	220.000	5.874	0.000	.122	116.34	0.00	2.44	118.79
13	*	240.000	5.760	0.000	.123	114.05	0.00	2.46	116.51
14	*	260.000	5.645	0.000	.123	111.73	0.00	2.47	114.20
15	*	280.000	5.528	0.000	.124	109.38	0.00	2.48	111.86
16	*	300.000	5.410	0.000	.124	107.00	0.00	2.49	109.50
17	*	320.000	5.290	0.000	.125	104.60	0.00	2.51	107.11
18	*	340.000	5.170	0.000	.126	102.19	0.00	2.52	104.71
19	*	360.000	5.049	0.000	.126	99.76	0.00	2.53	102.29
20	*	380.000	4.927	0.000	.127				

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STA ID		STATION NO.	PANEL RUNNING WEIGHT	INTERIOR WEB RUN. WEIGHT	SPAR-CAP/ LONGERON RUN. WT.	PANEL WEIGHT	INTERIOR WEB WEIGHT	SPAR-CAP/ LONGERON WEIGHT	TOTAL BAY WEIGHT
--	-	(IN)	(LB/IN)	(LB/IN)	(LB/IN)	(LBS)	(LBS)	(LBS)	(LBS)
21	*	400.000	4.804	0.000	.127	97.31	0.00	2.54	99.85
22	*	420.000	4.679	0.000	.128	94.83	0.00	2.55	97.38
23	*	440.000	4.553	0.000	.129	92.32	0.00	2.57	94.88
24	*	460.000	4.461	0.000	.129	90.14	0.00	2.58	92.72
25	*	480.000	4.403	0.000	.130	88.64	0.00	2.59	91.23
26	*	500.000	4.344	0.000	.130	87.47	0.00	2.60	90.07
27	*	520.000	4.284	0.000	.131	86.28	0.00	2.62	88.90
28	*	540.000	4.223	0.000	.132	85.08	0.00	2.63	87.70
29	*	560.000	4.162	0.000	.132	83.85	0.00	2.64	86.49
30	*	580.000	4.100	0.000	.133	82.61	0.00	2.65	85.27
31		600.000	4.037	0.000	.133	81.37	0.00	2.66	84.03
32	*	620.000	3.887	0.000	.133	79.25	0.00	2.66	81.91
33	*	640.000	3.741	0.000	.132	76.28	0.00	2.65	78.93
34	*	660.000	3.597	0.000	.131	73.37	0.00	2.64	76.01
35	*	680.000	3.456	0.000	.131	70.53	0.00	2.62	73.15
36	*	700.000	3.319	0.000	.130	67.75	0.00	2.61	70.36
37	*	720.000	3.185	0.000	.129	65.04	0.00	2.59	67.63
38	*	740.000	3.053	0.000	.129	62.38	0.00	2.58	64.96
39	*	760.000	2.925	0.000	.128	59.78	0.00	2.57	62.35

***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STA ID		STATION NO.	PANEL RUNNING WEIGHT	INTERIOR WEB RUN. WEIGHT	SPAR-CAP/ LONGERON RUN. WT.	PANEL WEIGHT	INTERIOR WEB WEIGHT	SPAR-CAP/ LONGERON WEIGHT	TOTAL BAY WEIGHT
--	-	(IN)	(LB/IN)	(LB/IN)	(LB/IN)	(LBS)	(LBS)	(LBS)	(LBS)
						57.25	0.00	2.55	59.80
40	*	780.000	2.800	0.000	.127				
						54.78	0.00	2.54	57.31
41	*	800.000	2.678	0.000	.127				
						52.36	0.00	2.52	54.88
42	*	820.000	2.558	0.000	.126				
						50.01	0.00	2.51	52.52
43	*	840.000	2.442	0.000	.125				
						47.71	0.00	2.50	50.21
44	*	860.000	2.329	0.000	.124				
						45.47	0.00	2.48	47.96
45	*	880.000	2.219	0.000	.124				
						43.30	0.00	2.47	45.76
46	*	900.000	2.111	0.000	.123				
						41.17	0.00	2.45	43.63
47	*	920.000	2.006	0.000	.122				
						[illegible].11	0.00	2.44	41.55
48	*	940.000	1.905	0.000	.122				
						37.10	0.00	2.43	39.53
49	*	960.000	1.806	0.000	.121				
						35.15	0.00	2.41	37.56
50	*	980.000	1.709	0.000	.120				
						33.25	0.00	2.40	35.65
51	*	1000.000	1.615	0.000	.120				
						31.40	0.00	2.38	33.78
52	*	1020.000	1.524	0.000	.119				
						29.60	0.00	2.37	31.97
53	*	1040.000	1.436	0.000	.118				
						27.86	0.00	2.36	30.22
54	*	1060.000	1.351	0.000	.117				
						26.19	0.00	2.34	28.53
55	*	1080.000	1.268	0.000	.117				
						24.57	0.00	2.33	26.90
56	*	1100.000	1.189	0.000	.116				
						23.02	0.00	2.31	25.33
57	*	1120.000	1.113	0.000	.115				
						4.20	0.00	.44	4.64
58		1123.800	1.099	0.000	.115				

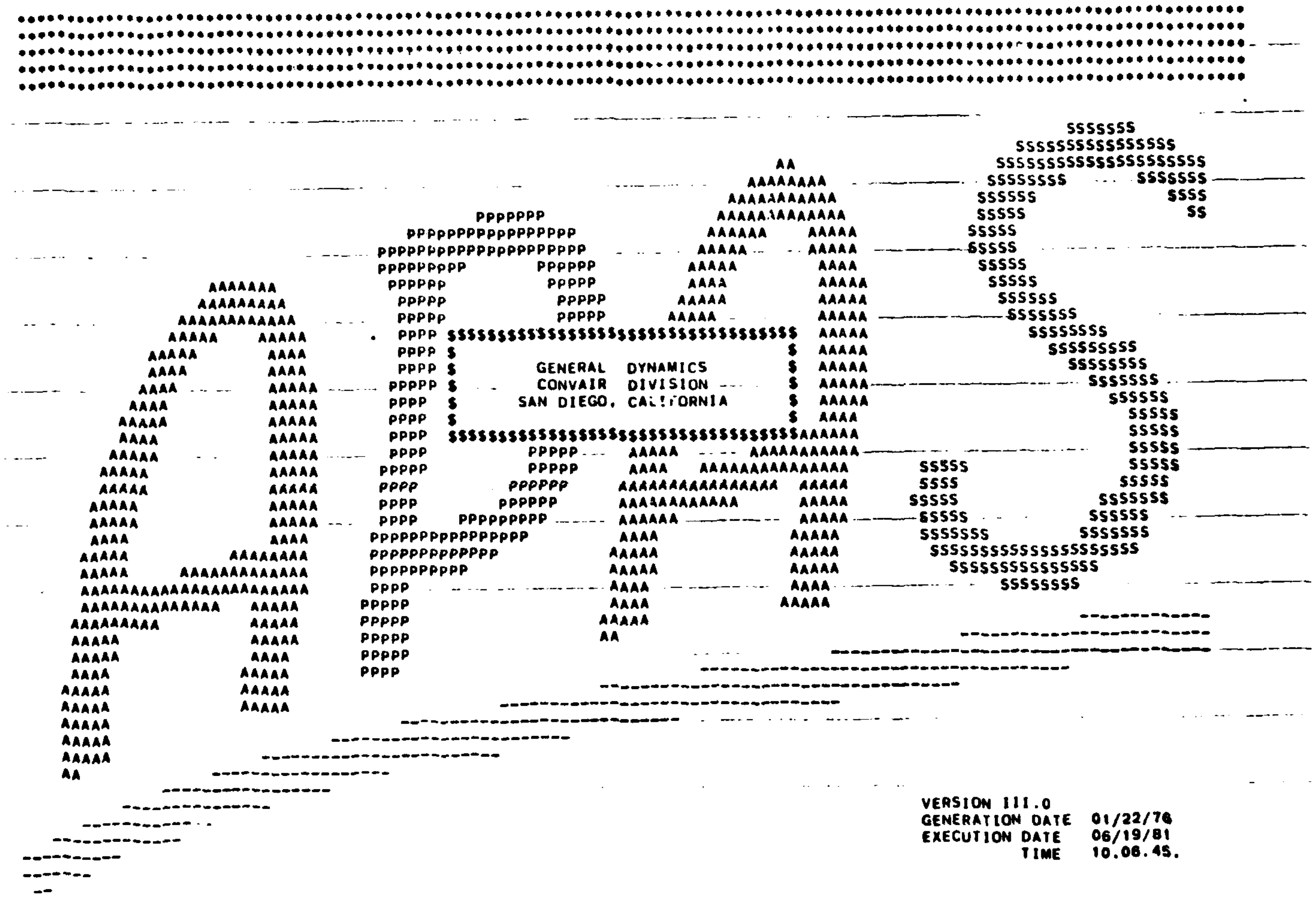
***** NARROW-BODIED, 4-ENGINE JET TRANSPORT, WING SYNTHESIS *****
AL-2024-T62 SKINS, AL-7075-T6 STIFFENERS, TI-6-4 RIBS AND SPARS

STA ID	STATION NO.	PANEL RUNNING WEIGHT	INTERIOR WEB RUN. WEIGHT	SPAR-CAP/ LONGERON RUN. WT.	PANEL WEIGHT	INTERIOR WEB WEIGHT	SPAR-CAP/ LONGERON WEIGHT	TOTAL BAY WEIGHT
-- -	(IN)	(LB/IN)	(LB/IN)	(LB/IN)	(LBS)	(LBS)	(LBS)	(LBS)
					4516.49	0.00	139.74	
						TOTAL SHELL WEIGHT =		4656.23
						TOTAL RIB/FRAME WEIGHT =		1291.50
						TOTAL STRUCTURE WEIGHT =		5947.73

* INDICATES STATIONS FOR WHICH WEIGHT RESULTS WERE INTERPOLATED.

JOB LOG

MODULE	CP TIME	PP TIME	MTR REQUESTS	CALLS
HEADER10	.091	0	0	1
INCON20	.405	0	0	1
STATION30	.036	0	0	3
REDCON41	1.728	0	0	19
OPTCON42	7.975	0	0	13
RECFAT43	6.037	0	0	6
RECGRO44	3.952	0	0	6
RECRES45	.139	0	0	3
STAOUT50	.539	0	0	3
TOTOUT	.363	0	0	3
TOTAL	21.265	0	0	58



VERSION III.0
GENERATION DATE 01/22/76
EXECUTION DATE 06/19/81
TIME 10.06.45.

Rockwell International

SECTION V

OPERATING INSTRUCTIONS

5.1 INITIATE THE COMPUTER PROGRAM

This computer program runs on the Network Operating System (NOS BE 1.0). It is written in FORTRAN IV for use with the FTN compiler.

This section shows a set of control cards, Figure 5-1, (catalog procedures) for operating this program. The first card is a GEMS control card which puts the procedure into the system. This is covered in more detail in the users manual volume for GEMS. This procedure attaches a preprocessor, executes it to retrieve data from the data base and puts it into the format needed by the program. Before attaching and executing the program, sense switch 1 is set to signal the program that the data is coming from Tape 2 instead of Tape 5 input. After the program has executed, the post-processor is attached, is executed to store data into the data base for use by other program modules. Finally, the GEMS procedure is called to bring the executive back into core.

This program can operate using Tape 5 as the input file by removing the switch 1 and pre/post processor control cards. This then will operate as a standalone program, independent of the overall system.

5.2 UPDATING PROCEDURES

This program can be modified by using the standard CDC UPDATE utility, that is by using the *I and *D for inserting and deleting desired code. However, if the program is modified, new relocatable binary and task files will need to be made. The catalog procedure shown in Figure 5-1 will accomplish this by taking the following steps:

```
ATTACH,PROFIL,FILENAME,ID=NAME
BEGIN,PLBDECK,,PL,LG,TSK,IDN.
```

NOTES:

- Procedure is attached as PROFIL.
- PLBDECK is name of procedure.
- PL = file name of the OLDPL.
- LG =name desired for relocatable binary.
- TSK = name of desired TASKFIL.
- IDN = desired ID name.

For information involving UPDATE DECK names, refer to the compilation listings of the program. For information involving the use of the UPDATE capabilities, refer to the Systems UPDATE Manual.

```
CATLG,PROCS.STEP.APAS.BATCH
ATTACH,PRE,PREPOST,ID=REED76047.
PRE,*DATA.
REWIND,APASI.
RETURN,PRE.
IF,SSW,-1,1.
SWITCH,1.
IF,SSW,-6,1.
SWITCH,6.
IF,BATCH,1.
SWITCH,6.
ATTACH,TASK,APASTSK,ID=REED76047.
TASK.
RETURN,TASK,APASI.
ATTACH,POST,PREPOST,ID=REED76047.
REWIND,APASO1,APASO2.
POST,*DATA.
RETURN,POST,APASO1,APASO2.
RETURN,*DATA.
BEGIN,GEMS,ACJCL.
/DATA
APASI
/EOR
APASO1
LINKSPEC
APASO2
LINKSPEC
/EOR
/EOF
END
```

Figure 5-1. Procedure for Executing APAS.

This program uses segmentation instead of overlay. Figure 5-2 represents the segmentation directives used for the segload sequences.

```
ROOT      TREE      AFAS-(HEADER,TINCON,TRANFRF,SUBFLT,TOTOUT)
TINCON    TREE      INCON-(MATIN,[illegible],GINPT2,GINPT3,GINPT4,LDLN1,LDLN2,L
,LDLN3,LDLN4,PROFLT,FATTIN,LIFE,FMDIN)
TRANFRF   TREE      PANFRF-(TOTOUT,TRDCFT)
TGDCSTA   TREE      GEDSTA-(STATIC-(LOADS,PREMAT),STAOUT-RIF)
TREDCFT   TREE      REDCFT-(CRIPLE-(REDCON,OPTCON),RECFAT,CHKDAT-(RECCRC,R
,ECRES),FRAME)
AFAS      INCLUDE   AFAS,L[illegible],[illegible]T,TIMIT,[illegible]LIM
TOTOUT    INCLUDE   TOTOUT
HEADER    INCLUDE   HEADER
INCON     INCLUDE   INCON
MATIN     INCLUDE   MATIN,[illegible]ATT[illegible],[illegible]
GINPT1    INCLUDE   GINPT1,CHK[illegible]T,SUBIN1,SUBIN2,LIN[illegible],LINKIN,[illegible]
GINPT2    INCLUDE   GINPT2
GINPT3    INCLUDE   GINPT3
GINPT4    INCLUDE   GINPT4
LDLN1     INCLUDE   LDLN1
LDLN2     INCLUDE   LDLN2
LDLN3     INCLUDE   LDLN3
LDLN4     INCLUDE   LDLN4
PROFLT    INCLUDE   PROFLT,PR[illegible]T,[illegible]
FATTIN    INCLUDE   FATTIN,FATTE1,FATTE2,FATTE3,RANFIL
LIFE      INCLUDE   LIFE
FMDIN     INCLUDE   FMDIN,[illegible]
PANFRF    INCLUDE   PANFRF
GEDSTA    INCLUDE   GEDSTA,I[illegible],LOCATE,STAGE,NISHEL,TC[illegible]N
STATIC    INCLUDE   STATIC
LOADS     INCLUDE   LOADS
PREMAT    INCLUDE   PREMAT
STAOUT    INCLUDE   STAOUT,F[illegible]T,STORE,RUN[illegible]T,SAV[illegible]T,S[illegible]INT,S[illegible],LOCALP
RIF       INCLUDE   RIF,LOAD2
REDCFT    INCLUDE   REDCFT,C[illegible],T[illegible],[illegible]CALDS,I[illegible]STIF,N[illegible]TE,[illegible],S[illegible]
,SORT,SF[illegible]
CRIPLE    INCLUDE   CRIPLE,CRI[illegible],BUCKLE,EFFSK[illegible],EVA,[illegible],LOCBUK,[illegible]
,GIN,MUPL1,S[illegible] ,SETPRF,S[illegible],[illegible]1,WEB2
REDCON    INCLUDE   REDCON,LOCAL[illegible]
OPTCON    INCLUDE   OPTCON,CU[illegible],[illegible],L[illegible]CCFT,[illegible],ONE[illegible],[illegible]
RECFAT    INCLUDE   RECFAT,EVAL,[illegible],[illegible],SLAFIT,RANFIL,[illegible]
CHKDAT    INCLUDE   CHKDAT,CHK[illegible],USIG,[illegible]EDAT,SLIN,[illegible]
RECCRC    INCLUDE   RECCRC,EVA[illegible],[illegible],SIGBAR,PRECRO,CLA[illegible],FLT[illegible]RO,CO
,RREC,CRITIC
RECRES    INCLUDE   RECRES,EVA[illegible],[illegible],LOCALD
FRAME     INCLUDE   FRAME,TF[illegible]
SUBOUT    INCLUDE   SUBOUT
AFAS      GLOBAL    [illegible]L1,C[illegible],COPT1,[illegible]1,FATT2,F[illegible]LT1,F[illegible],[illegible]1,C[illegible],G
,E[illegible]3,C[illegible]4,[illegible],[illegible],[illegible],[illegible]YS1,LCLD1,L[illegible]1,LIF[illegible]1,LI[illegible]1,LINK2,
,LOAD1,LOAD2,LOAD[illegible],I[illegible]1,[illegible],[illegible]ATT3,MATT4,MATT5,PA[illegible]1,PASS1,P[illegible]CT1,SLCF1
,,SIZE1,SIZE2,SI[illegible]3,[illegible],TITL1
AFAS      GLOBAL    [illegible]
REDCFT    GLOBAL    [illegible],INDX1,[illegible],MATT[illegible]
STAOUT    GLOBAL    ST[illegible]
CHKDAT    GLOBAL    FA[illegible]L1,CRA[illegible]1,[illegible]1
AFAS      GLOBAL    TSTAY,TAIL1,[illegible]PT1,[illegible]
TOTOUT    GLOBAL    [illegible]TS-[illegible]
PROFLT    GLOBAL    P[illegible],[illegible]
RECCRC    GLOBAL    STA[illegible]
          END
```

Figure 5-2. Segmentation Directives

```
PLBDECK (PL, LG, TSK, ISG, IDN)
ATTACH (OLDPL, PL, ID=IDN)
UPDATE (F, I=DUM)
RETURN (DUM)
RETURN (OLDPL)
REQUEST (LGO, *PF)
FTN (I=COMPILE, R=3)
CATALOG (LGO, LG, ID=IDN)
REWIND (LGO)
MAP (ON)
ATTACH (SEG, ISG, ID=IDN)
SEGLOAD (I-SEG, B-ABS)
LOAD (LGO)
NOGO.
RETURN (LGO)
REQUEST (TASKFIL, *PF)
EDITLIB (USER, I=PROFIL)
CATALOG (TASKFIL, TSK, ID=IDN)
RETURN (ABS, TASKFIL)
REVERT.
7
 8
  9
LIBRARY (TASKFIL, NEW)
REWIND (ABS)
ADD (*, ABS)
FINISH.
ENDRUN.
6
 7
  8
   9
```

Figure 5-3. Procedure for Creating a TASKFIL

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